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| (54) Title: ECK RECEPTOR LIGANDS (57) Abstract Ligands which bind to the <i>eck</i> receptor are disclosed. More particularly, polypeptides which bind specifically to the <i>eck</i> receptor <i>eck</i> receptor binding proteins or EBPs) and DNA sequences encoding said polypeptides are disclosed. Methods of treatment using <i>eck</i> receptor ligands and soluble <i>eck</i> receptor and disclosed, as are pharmaceutical compositions containing same. A rapid and sensitive method for the detection of receptor binding activity in crude samples is provided. | | |

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ECK RECEPTOR LIGANDS

The invention relates generally to ligands of the eck receptor and, in particular, to polypeptide ligands termed eck receptor binding proteins (EBPs). Also encompassed by the invention are methods of treatment using eck receptor ligands and soluble eck receptor, and pharmaceutical compositions containing same. A rapid and sensitive method for the detection of receptor binding activity in crude samples is described.

Background of the Invention

Peptide growth and differentiation factors elicit responses in target cells by means of specific interactions with receptors at the cell surface. Growth factor receptors are typically membrane glycoproteins with distinct extracellular, transmembrane, and intracellular domains. The structural segregation of the domains corresponds to function (Ullrich et al. *Cell* 61, 203 (1990)); the extracellular domain appears to be responsible for ligand binding and ligand-mediated receptor dimerization (Cunningham et al. *Science* 254, 821 (1991); Lev et al. *J. Biol. Chem.* 267, 10866 (1992)), while the intracellular domain of the receptor, or the intracellular domain of an accessory element (Takeshita et al. *Science* 257, 379 (1992)), is responsible for signal transduction. Much of the specificity of growth factor activity is dictated by the interaction with the binding site on the extracellular domain of the cognate receptor. Chimeric receptors, engineered to contain the extracellular domain of one receptor and the intracellular domain of a second receptor, retain the ligand specificity of the extracellular component (Lehvaslaiho et al. *EMBO J.* 8, 159 (1989)). The downstream signaling pathways

activated by such chimeric receptors correspond to those activated by the intracellular component. In many cases soluble forms of receptors, consisting of only the extracellular domains, retain ligand binding activity
5 (Lev et al. *ibid*; Duan et al. *J. Biol. Chem.* 266, 413 (1991)). Truncated receptors have been identified in serum (Fernandez-Botran *FASEB J.* 5, 2567 (1991)), cell culture supernatants (Zabrecky et al. *J. Biol. Chem.* 266, 1716 (1991)), and have been produced through
10 recombinant techniques (Lev et al. *ibid*, Duan et al. *ibid*).

Recent progress in nucleic acid sequencing and amplification technologies has resulted in the identification of an increasing number of genes which
15 code for previously unidentified growth factor receptors (Wilks *Proc. Natl. Acad. Sci. USA* 36, 1603 (1989); Lai et al. *Neuron* 6, 691 (1991)). As a result, there is a demand to develop procedures which can define the biological roles of orphan receptors, including
20 techniques which can identify ligands for these receptors (McConnell et al. *Science* 257, 1906 (1992)). Receptor affinity technology is one approach to this problem. This technology may augment existing strategies for the isolation of novel growth factors,
25 since it allows the detection of ligands when biological responses are subtle or undefined.

Recent reports have suggested that the extracellular domains of receptors can be exploited as growth factor-specific affinity reagents. Bailon et al.
30 (*Biotechnology* 5, 1195 (1987)) have shown that the extracellular domain of the IL-2 receptor α subunit can be immobilized on chromatographic media and used for the purification of recombinant IL-2. A genetic fusion of the *kit* extracellular domain with an alkaline
35 phosphatase enzymatic tag allowed the identification of a cell associated ligand for the receptor (Flanagan

- 3 -

et al. *Cell* 63, 185 (1990)). Lupu et al. (*Proc. Natl. Acad. Sci. USA* 89, 2287 (1992)) have reported the affinity purification of an activity which binds to the immobilized extracellular domain of the *erbB-2* gene product.

The *eck* gene, originally identified by cDNA cloning from a human epithelial cell library, encodes a 130 kDa receptor-like protein-tyrosine kinase (p130^{*eck*}) (Lindberg et al. *Mol. Cell. Biol.* 10, 6316 (1990)).

10 Immunohistochemical and mRNA screening of tissues and cell lines suggest that *eck* expression is highest in cells of epithelial origin. By analogy with genes encoding other receptor-like protein-tyrosine kinases, *eck* may be a proto-oncogene and therefore may have a

15 role in carcinogenesis. This potential role for *eck* is more likely given the frequent involvement of epithelial cells in human cancers. Receptor protein kinases are typically activated through interaction with one or more ligands. However, a ligand capable of activating

20 p130^{*eck*} has not yet been reported. The identification of such a ligand may be important in defining the role of p130^{*eck*} activation in the development of some human cancers.

It is therefore an object of this invention to

25 identify one or more ligands for p130^{*eck*}. The possible role of p130^{*eck*} in the transformation of epithelial cells to a cancerous state suggests that identification of the ligand responsible for receptor activation may have therapeutic implications for some epithelial cell-

30 derived malignancies.

SUMMARY OF THE INVENTION

The present invention generally relates to *eck*

35 receptor ligands. More particularly, polypeptides which bind specifically to the *eck* receptor, herein referred

to as eck receptor binding proteins (EBPs), are disclosed. EBPs were identified and isolated by affinity chromatography using immobilized extracellular eck receptor. EBPs of the present invention may also
5 induce phosphorylation of the receptor upon binding which may trigger changes in target cell physiology, e.g. cell growth and/or differentiation. EBP has an amino acid sequence substantially as shown in SEQ. ID. NO. 1. In a preferred embodiment, EBP has a portion of
10 the amino acid sequence as shown in SEQ. ID. NO. 1. For example, EBP has an amino acid sequence terminating at position 150.

A polypeptide specifically binding the eck receptor, wherein the polypeptide has substantially the
15 same amino acid sequence as shown in SEQ. ID. NO. 1 and has a methionine residue at position -1 is also included. By way of example, the polypeptide is [Met⁻¹] EBP¹⁻¹⁵⁰ or [Met⁻¹] EBP¹⁻¹⁵⁹. Also provided for are DNA sequences encoding same. EBPs may also be analogs which
20 have a portion of the amino acid sequence as shown in SEQ. I.D. NO. 1. Examples of such analogs are EBPs terminating at positions 167, 171 or 180.

The invention also provides for EBP as a product of procaryotic or eucaryotic expression of an
25 exogenous DNA sequence, i.e., eck receptor binding protein is derived from recombinant DNA methods.

A method for detecting receptor binding activity in crude samples by monitoring the binding to an immobilized ligand binding domain of a receptor is
30 also encompassed by the invention.

Pharmaceutical compositions comprising a therapeutically effective amount of an eck receptor ligand are described. Also included is the use of an
eck receptor ligand in the treatment of certain types of
35 cancers, particularly those characterized by epithelial cell proliferation. eck receptor ligands may also be

used for the treatment of wounds to promote healing, for increasing hematopoiesis, and for stimulating the proliferation of hepatocytes and colon crypt cells.

The use of therapeutically effective amounts
5 of ligand antagonists or soluble eck receptor for modulating the biological effects of eck receptor ligands is also encompassed by the invention. Such treatments are useful in cancer therapy and in the control of inflammation.

10

BRIEF DESCRIPTION OF THE FIGURES

Figure 1A. SDS-PAGE analysis of immobilized eck-x affinity chromatography. Conditioned medium from
15 HCT-8 cells was concentrated, diafiltered, and loaded onto a 1 ml column of immobilized eck-x (1 mg eck-x per ml of gel). Samples were concentrated in the presence of 0.02% SDS when necessary; equivalent original volumes are shown in parentheses. Lane 1, Column load (20 ml).
20 Lane 2, Unbound fraction (20 ml). Lane 3, PBS wash (50 ml). Lane 4, pH 4.0 elution, fraction 1 (200 ml). Lane 5, pH 4.0 elution, fraction 2 (200 ml). Lane 6, pH 4.0 elution, fraction 3 (200 ml).

25 Figure 1B. SDS-PAGE analysis of immobilized eck-x affinity chromatography. Cell supernatants from CHO cells transfected with EBP gene were treated and analyzed as described in legend to Figure 1A.

30 Figure 2. Gel Filtration analysis of purified EBP from HCT-8 cell line. EBP, purified by immobilized eck-x receptor affinity chromatography, was amended with 50 µg/ml BSA and injected onto a Superdex 75 column. Fractions were tested for eck-x binding activity by
35 BIAcore.

Figure 3. Q-Sepharose chromatography of EBP from CHO cells transfected with EBP cDNA. Samples were analyzed by SDS-PAGE and probed with anti-EBP antibody.

5 Figure 4. Analysis of release of membrane-bound EBP from CHO cell surfaces by phospholipase C treatment. "-" indicates incubation in the absence of phospholipase C; "+" indicates incubation in the presence of phospholipase C. Time of incubation was 0,
10 5 and 10 minutes.

 Figure 5. Chemical crosslinking of ^{125}I -rEBP to CHO 19.32 cells expressing *eck*. Cells were treated as described in Example 5. Lane 1, ^{125}I -rEBP +
15 CHO 19.32 Lane 2, ^{125}I -rEBP + CHOd- (untransfected). Lane 3, ^{125}I -rEBP + CHO 19.32, no crosslinker added. Lane 4, ^{125}I -rEBP + CHO 19.32 + 50X unlabelled rEBP.

 Figure 6. Activation of the *eck* receptor
20 tyrosine kinase in LIM 2405 cells treated with purified rEBP. Serum-starved LIM 2405 cells were treated for 10-15 min at 37°C with increasing concentration of purified rEBP (CHOd-/EBP). The treated cells were lysed and then immunoprecipitated with anti-*eck* C-terminal antibody.
25 The immunoprecipitates were split into two equal samples and resolved in parallel in a 7.5% SDS polyacrylamide gel. The gel was blotted onto membrane, then probed with either monoclonal anti-phosphotyrosine antibody (upper panel) or anti-*eck* C-terminus (lower panel).
30 Migration of the *eck* polypeptide is marked by an arrowhead.

 Figure 7. Binding of CHO-derived EBP in various detergent formulations to immobilized *eck*
35 receptor as measured by BIAcore. Purified EBP was diluted to 100 µg/ml in PBS in the presence or absence

of detergent and incubated for 2 hrs. at 3°C. Protein samples were diluted to the concentrations indicated in the figure and tested for eck receptor binding.

5 Figure 8. CFU-C and CFU-Mk formation in bone marrow cultures in the presence of EBP alone and in combination with IL-3, erythropoietin or GM-CSF.

10 Figure 9. Incorporation of ³H-thymidine in hepatocyte cultures in the presence of EBP, acidic FGF or KGF.

DETAILED DESCRIPTION OF THE INVENTION

15 The present invention relates to ligands which bind to the eck receptor, a 130 kDa protein tyrosine kinase identified by Lindberg et al., supra. An eck receptor ligand may activate the receptor by inducing autophosphorylation by the protein-tyrosine kinase
20 catalytic domain. Protein-tyrosine kinases are part of the signal transduction pathway which modulates cell proliferation and differentiation. Therefore, a ligand capable of activating protein-tyrosine kinase activity
25 of the eck receptor will likely be important in modulating the growth and differentiation of cells expressing the receptor. An eck receptor ligand may be a polypeptide, peptide, or non-protein molecule which binds to and/or activates the eck receptor.

 The present invention provides for novel
30 polypeptides which specifically bind to the eck receptor. These polypeptides are referred to as eck binding proteins, or EBPs. EBPs have been isolated from the conditioned medium of SK-BR-3 and HCT-8 cell lines by receptor affinity chromatography using the eck
35 receptor extracellular domain (eck-x) as the affinity reagent. Construction of the eck-x gene and expression

and purification of eck-x are described in Example 1. The purification of eck binding proteins on immobilized eck-x is described in Example 3A.

EBP derived from the HCT-8 cell line exists in several different molecular weight forms in the range of 21-27 kDa as revealed by SDS-PAGE (Figure 1A). N-terminal sequencing of EBPs in the 21-27 kDa range revealed a single sequence (Example 3B). After enzymatic removal of carbohydrate chains, a mixture of species in the range of 17-19 kDa was observed, suggesting that the different forms may result from alternative post-translational processing of the protein.

The N-terminal sequence of SK-BR-3 derived EBP was identical to the N-terminal amino acid sequence predicted from the expression of the B61 gene (Holzman et al. *Mol Cell. Biol.* 10, 5830 (1990); PCT Application No. WO 92/07094). The B61 gene was originally identified by differential hybridization as an immediate-early response gene and its expression was induced in cultured human vascular endothelial cells by treatment with tumor necrosis factor- α . Based upon the sequence of the EBP gene, the encoded protein was predicted to have 187 amino acids in its mature form. The isolation and characterization of the EBP-encoded protein has not been previously reported. It was proposed that the EBP protein functions as a cytokine-induced marker for inflammation and therefore is useful as a diagnostic reagent for the detection of an impending inflammatory response (PCT Application No. WO 92/07094).

cDNA encoding EBP having the N-terminal sequence determined in Example 3B was cloned and sequenced and, as expected, found to be identical to the B61 gene (Holzman et al. supra). The B61 DNA sequence reported by Holzman et al. is shown in SEQ. ID. NO. 11.

- 9 -

The EBP (or EBP gene) was expressed in CHO cells and in *E. coli* as described in Example 4. At least two polypeptides having different molecular weights were expressed by the EBP gene in CHO cells. C-terminal sequencing of CHO cell EBP revealed only the sequence -lys-arg-leu-ala-ala-COOH which indicated a polypeptide of 150 amino acid residues. This polypeptide is referred to as EBP¹⁻¹⁵⁰. A polypeptide of 187 amino acids corresponding to the predicted EBP protein, if present at all, represents a very minor product of CHO cell expression. Expression of the EBP gene (lacking the leader sequence) in *E. coli* resulted in a single product on SDS-PAGE having a C-terminal sequence predicted for the full-length protein. This polypeptide which has a methionine residue at the amino terminus is designated [met-1] EBP¹⁻¹⁸⁷ and, with the exception of the N-terminal met, is identical in amino acid sequence to the predicted EBP protein.

CHO cell-derived rEBP has been shown to interact with the *eck* receptor by the following experiments (see also Example 5): 1) Crosslinking of CHO rEBP to colon carcinoma cells naturally expressing the *eck* receptor or to CHO cells transfected with the *eck* gene; 2) equilibrium binding studies of CHO rEBP to *eck* receptors on colon carcinoma cells; and 3) stimulation of *eck* receptor phosphorylation on colon carcinoma cells. Induction of receptor phosphorylation by CHO rEBP indicates that the ligand may be able to effect a biological response (e.g., growth or differentiation) in cells displaying the *eck* receptor.

It is apparent that EBP may be expressed in a number of different molecular weight forms, more than one of which may be biologically active. Various forms of EBP are produced naturally by human cell lines and by EBP gene-transfected host cells as shown in Figures 1A and 1B. As shown in Figure 3, EBP from transfected CHO

cells was isolated as two different molecular weight forms of 22 kDa (major) and 24 kDa (minor). Characterization of these different forms revealed two distinct EBPs of 150 and 165 amino acids, designated EBP¹⁻¹⁵⁹ and EBP¹⁻¹⁵⁹. Phosphoinositol-phospholipase C treatment of EBP-transfected CHO cell lines releases soluble EBP, strongly suggesting a glycolipid form of EBP. Isolated 27 kDa forms of EBP are susceptible to digestion with phospholipase D further suggesting that these forms are solubilized forms of glycopospholipid-anchored EBP.

The invention provides for EBP having the activity of specifically binding to the *ec*k receptor and having substantially the same amino acid sequence as shown in SEQ. ID. NO. 1. The term "substantially the same amino acid sequence" as used herein refers to deletions or substitutions of amino acids in SEQ. ID. NO. 1 such that the resulting polypeptides specifically bind the *ec*k receptor. As described above, EBP also induces phosphorylation of the *ec*k receptor. However, the present invention encompasses polypeptides which bind the *ec*k receptor and may or may not induce receptor phosphorylation. In a preferred embodiment, EBP has a portion of the amino acid sequence as shown in SEQ. ID. NO. 1. For example, EBP has the amino acid sequence as shown in SEQ ID. NO. 1 terminating at position 150 or has substantially the same amino acid sequence as shown in SEQ. ID. NO. 1 Preferably, EBP is EBP¹⁻¹⁵⁰, that is, it has the amino acid sequence from positions +1 to 150 as shown in SEQ. ID. NO. 1.

An EBP which has substantially the same amino acid sequence as shown in SEQ. ID. NO. 1 and has a methionine residue at position -1 is also included. [Met-1] EBP¹⁻¹⁵⁰ and [Met-1] EBP¹⁻¹⁵⁹ are examples. Also provided for are DNA sequence encoding same. A truncated DNA sequence encoding amino acid residues +1

to 150 as shown in SEQ. ID. NO. 1 was constructed and expressed in *E. coli*. The resulting protein, [met-1] EBP¹-150, binds to the eck receptor and induces receptor phosphorylation (Example 6).

5 Also encompassed by the invention are fragments and analogs of the polypeptide encoded by the amino acid sequence shown in SEQ. ID. NO. 1 wherein said fragments and analogs bind to the eck receptor, and DNA sequences encoding said fragments and analogs. Included
10 are fragments having deletions from the N-terminal or C-terminal ends of the polypeptide as shown in SEQ. ID. NO. 1 and deletions from internal regions. Examples of EBP fragments include EBP¹-167, EBP¹-171 and EBP¹-180 described in Example 5. Analogs include amino acid
15 substitutions at one or more sites in the polypeptide. Fragments and analogs of the invention are readily constructed using recombinant DNA techniques which are known to those skilled in the art. The biological activity of the resulting fragments and analogs is
20 readily tested by binding to eck soluble receptor or to eck receptors on cell surfaces and by inducing phosphorylation of the eck receptor.

The invention also includes EBP characterized by being the product of procaryotic or eucaryotic
25 expression of an exogenous DNA sequence, i.e., EBP is recombinant EBP. Exogenous DNA sequences may be cDNA, genomic or synthetic DNA sequences. EBP may be expressed in bacterial, yeast, plant, insect or mammalian cells in culture or in transgenic animals.
30 DNA vectors suitable for the expression of EBP in a variety of host cells are known to one skilled in the art. Examples of such vectors are pDSR α 2 for the expression of EBP gene in CHO D- cells and pCFM1156 for the expression of EBP gene in *E. coli*.

35 EBP expression in *E. coli* results in the formation of insoluble inclusion bodies. Recovery of

biologically active EBP requires solubilization of EBP aggregates followed by refolding of the solubilized protein. Example 4C describes a refolding procedure for *E. coli* derived EBP which yields EBP active in eck-x binding and eck phosphorylation. EBP refolding procedures may be modified to increase the activity of the renatured protein and to increase the yield of active EBP. Such modifications include changing the denaturant used to solubilize the inclusion body (e.g. using guanidinium chloride vs. urea), the oxidizing agent (which may include oxidation reduction pairs such as oxidized and reduced glutathione), or the dilution protocol from the denaturant (e.g. EBP may be diluted at a different protein concentration into a detergent containing buffer at a modified pH).

Also provided by the invention is a method for detecting a ligand present in crude samples, e.g., conditioned medium, which is capable of binding a receptor. The method comprises the steps of:

- a) immobilizing a purified ligand binding domain of the receptor;
- b) contacting the immobilized receptor with conditioned medium containing the ligand; and
- c) monitoring the binding of the ligand to the immobilized receptor by a surface plasmon resonance detection system.

As described in Example 2, this method provides a rapid and sensitive screening for eck receptor binding activity in cell supernatants. The results of this screening are shown in Table 1. Although the method is used to detect eck binding activity, it may be generally applied to any receptor-ligand interaction. Any ligand binding domain of a receptor may be immobilized for the isolation of receptor binding proteins. In a preferred embodiment, the ligand binding domain is the extracellular domain or

a fragment or analog thereof which is competent for binding. In addition to screening cell supernatants, the method may also be used to screen mixtures of random sequence peptides for receptor binding.

5 The invention provides, for the first time, a method of modulating the endogenous enzymatic activity of an eck receptor. Said method comprises administering to a mammal an effective amount of a ligand to the eck
10 receptor. eck receptor enzymatic activity regulates cellular functions comprising differentiation, proliferation and metabolism. In a preferred embodiment, EBP, or a fragment or analog thereof, is the ligand. However, other ligands may also be used in
15 modulating eck receptor activity, for example, polypeptides not related to EBP, or peptides and non-protein organic molecules.

Also encompassed by the invention is a method for identifying compounds that modulate the activity of
20 an eck receptor. Said method comprises the steps of:

a) exposing cells exhibiting the receptor to known ligands for a time sufficient to allow formation of receptor-ligand complexes and induce signal transduction;

25 b) determining the extent of activity within the cells; and

c) comparing the measured activity to the activity in cells not exposed to the ligand. Eck receptor activity may be detected by changes in
30 target cell proliferation, differentiation or metabolism. A description of methods relating to the modulation of eck receptor activity on hematopoietic progenitor cells, colon crypt cells and hepatocytes appears in Example 9.

35 The invention also encompasses an isolated eck receptor-ligand complex which results from the

interaction of the eck receptor with a ligand such as EBP. The interaction may result in activation of the receptor and transduction of a signal which modulates the physiological state of the receptor-bearing cells.

- 5 Preferably, the ligand acts as a growth factor to stimulate the proliferation of target cells. Alternatively, ligand binding may not activate the eck receptor. In this instance, the ligand may act as an antagonist for other molecules which activate the
10 receptor and induce in signal transduction.

The eck receptor is expressed primarily in tissues containing significant amounts of epithelial cells (e.g. lung and intestine) and in cell lines derived from epithelial cells (Lindberg et al., supra).

- 15 A ligand of the eck receptor may stimulate either the growth or differentiation of cells expressing the receptor. A ligand which induces differentiation of cells bearing the eck receptor may be useful in the treatment of certain types of cancers, particularly
20 those resulting from proliferation of epithelial cells. An eck receptor ligand may be used alone or in combination with standard chemotherapy or radiation therapy for cancer treatment.

- EBP interaction with the eck receptor may be
25 involved in the development of a cancerous state through stimulation of cell growth or may promote metastasis by stimulating cell mobility and adhesion. Several strategies are available for modulating the biological effects of EBP. Fragments or analogs of EBP which bind
30 to but do not activate the eck receptor are useful as EBP antagonists. Administration of an EBP antagonist having affinity for the eck receptor will block receptor binding and activation by circulating EBP. Administration of soluble eck receptor may also be used
35 to counteract the biological effects of EBP. Soluble eck receptor will compete with cell surface receptors

for binding to EBP and thereby reduce the extent of eck receptor activation by EBP. Soluble eck receptors suitable for therapeutic use include the receptor protein described in Example 1 as well as fragments and
5 analogs thereof which bind EBP. In addition, monoclonal antibodies directed either to EBP or to the eck receptor may be useful in blocking the interactions of EBP with eck receptors on cell surfaces.

Expression of the EBP gene in endothelial
10 cells has been shown to be stimulated by $\text{TNF-}\alpha$ and $\text{IL-1}\beta$, two proinflammatory cytokines which activate various functions in endothelial cells as part of the inflammatory response (Holzman et al. supra). A treatment comprising the administration of soluble eck
15 receptor to reduce levels of EBP that are increased during the inflammatory response may be useful in controlling inflammation.

A method for the treatment of a wound in a mammal comprising administering a therapeutically
20 effective amount of an eck receptor ligand is provided. As shown in Example 9A, EBP promoted an increase in tissue wet weight, total protein, total DNA, and total glycosaminoglycan in the rat wound chamber assay. Since EBP is expressed early in the inflammatory response, it
25 could play a role in the recruitment of epithelial cells to the site of an injury.

A method for increasing hematopoiesis in a mammal comprising administering a therapeutically effective amount of an eck receptor ligand is also
30 provided. As shown in Example 9B, EBP in combination with interleukin-3 (IL-3) shows a significant enhancement of CFU-Cs in mouse bone marrow cultures. EBP would be useful in restoring hematopoiesis when myelosuppression has occurred, either as a result of a
35 disease or after exposure to myelosuppressive agents, such as chemotherapeutic drugs or agents. In a

preferred embodiment, a therapeutically effective amount of EBP is used in combination with a therapeutically effective amount of IL-3 for increasing hematopoiesis.

Also included is a method for stimulating the proliferation of colon cells in a mammal comprising administering a therapeutically effective amount of an eck receptor ligand. As shown in Example 9C, EBP stimulates cell proliferation in a colon crypt assay. An eck receptor ligand such as EBP would be useful in alleviating gut toxicity following chemotherapy.

A method for stimulating proliferation of hepatocytes comprising administering a therapeutically effective amount of an eck receptor ligand is provided. Example 9D shows stimulation of hepatocytes by EBP. This stimulation is comparable to that seen in the same assay with acidic fibroblast growth factor (aFGF), a known hepatocyte growth factor. Treatment with an eck receptor ligand is useful for repairing liver damage resulting from disease or injury.

The invention provides for pharmaceutical compositions comprising therapeutically effective amounts of an eck receptor ligand together with pharmaceutically acceptable diluents, carriers, preservatives, emulsifiers and/or solubilizers. A "therapeutically effective amount" as used herein refers to that amount which provides therapeutic effect for a given condition and administration regimen. It is expected that one skilled in the art would be able to determine a therapeutically effective amount of an eck receptor ligand for any given condition being treated.

Pharmaceutical compositions include diluents of various buffers (e.g., Tris, acetate, phosphate), solubilizers (e.g., Tween, Polysorbate), carriers such as human serum albumin, preservatives (thimerosal, benzyl alcohol) and anti-oxidants such as ascorbic acid. As shown in Example 7, the ability of purified and

diluted EBP to bind to soluble eck receptor is prolonged when EBP is formulated in the presence of a stabilizing agent. The stabilizing agent may be a detergent, such as tween-20, tween-80, NP-40 or Triton X-100. EBP may also be incorporated into particulate preparations of polymeric compounds for controlled delivery to a patient over an extended period of time. A more extensive survey of components in pharmaceutical compositions is found in Remington's Pharmaceutical Sciences, 18th ed. A.R. Gennaro, ed. Mack, Easton, PA (1990).

EBP may be administered by injection, either subcutaneous, intravenous or intramuscular, or by oral or nasal administration. The route of administration will depend upon the particular condition being treated.

The following examples are offered to more fully illustrate the invention, but are not construed as limiting the scope thereof.

EXAMPLE 1

Production of eck receptor extracellular domain

A. Construction of an eck-x expression plasmid

A plasmid for mammalian expression of the extracellular domain of eck was generated in several steps beginning with pGEM3Z-eck, a 3.4kb EcoRI-Kpn I subclone of the eck cDNA (Lindberg et al. supra). Oligonucleotides 317-11 (5'-AGCTTAGATCTCC-3'; SEQ. ID. NO. 7) and 317-12 (5'-AATTGGAGATCTA-3'; SEQ. ID. NO. 8) were kinased and ligated to the 1.7kb EcoRI fragment of pGEM3Z-eck and pGEM4Z which had been digested with Hind III and EcoRI. A clone was selected which had the oligonucleotides added only to the 5' end of eck. Characteristics of this clone include the addition of Hind III and Bgl II sites and deletion of the 5' EcoRI

site adjacent to the *eck* sequence. The insert from this clone was isolated following digestion with Hind III and EcoRI and ligated to kinased oligonucleotides:

- 5 317-9 5'-AATTCCAGACGCTGTCCCCGGAGGGATCCGGCAACTGAG-3'
 (SEQ. ID: NO. 9) and
 317-10 5'-TCGACTCAGTTGCCGGATCCCTCCGGGGACAGCGTCTGG-3
 (SEQ. ID: NO. 10)

- 10 with pGEM4Z digested with Hind III and Sal I. This
 added a Bam HI site, a TGA stop codon following Asn⁵³⁴
 and a Sal I restriction enzyme site. The Hind III-Sal I
 fragment containing the coding sequence for the external
 domain of *eck* was then transferred to pDSR α 2 (deClerk
15 et al. *J. Biol. Chem.* 266, 3893 (1991)).

B. Mammalian cell expression of *eck* x

- The expression plasmid pDSR α -*eck*-x was
 introduced in CHO cells by calcium mediated transfection
20 (Wigler et al. *Cell* 11, 233 (1977)). Individual
 colonies were selected based upon expression of the
 dihydrofolate reductase (DHFR) gene in the plasmid and
 one clone, designated 21.021 was chosen for
 amplification. Expression of the *eck* gene was monitored
25 by RNA hybridization (Hunt et al. *Exp. Hematol.* 19, 779
 (1991)).

- Amplification of *eck* expression was done in
 10 nM methotrexate. Cell line 21.02 was expanded for
 production of *eck*-x. Roller bottles were seeded at 2 x
30 10⁷ cells in 200 ml DMEM:Ham's F12 (1:1) supplemented
 with non-essential amino acids, 10 nM methotrexate and
 5% FBS. Cells reached confluence in 3 days at which
 time fresh media lacking 5% FBS was added. Conditioned
 media was harvested and replaced after seven days and a
35 second harvest was taken after fourteen days.

- 19 -

C. Purification of eck-x

Conditioned medium from 21.02 cells was concentrated and diafiltered against 10 mM Tris-HCl, pH 7.4 using a 10,000 MWCO spiral wound filter (S1Y10, Amicon, Danvers, MA). The 50 mL concentrate was loaded onto an anion exchange column (Hema-Q, 10 μ m particle size, 1.6 x 12 cm, Separon, Sunnyvale, CA) and eluted with a linear gradient of 0-0.5 M NaCl in 10 mM Tris-HCl, pH 7.4. Fractions were analyzed by SDS-PAGE and western blotting using a rabbit antiserum generated against a synthetic N-terminal peptide of eck-x. Fractions containing eck-x were pooled, dialyzed against 10 mM Tris-HCl, pH 7.4, reloaded onto the Hema-Q column, and eluted and analyzed as before. The resulting pool was concentrated to 3 mL (centriprep-10, Amicon, Danvers, MA) and applied to a Superdex 200 (Pharmacia, Piscataway, NJ) gel filtration column (2.2 x 90 cm, flow rate 1.0 ml/min) equilibrated in PBS. A pool containing the purified eck-x was made and served as the basis of further experiments.

EXAMPLE 2

Screening of conditioned media
for binding to the eck extracellular domain

Interactions with eck-x were measured on a surface plasmon resonance detector system (BIAcore, Pharmacia Biosensor, Piscataway, NJ) using procedures recommended by the manufacturer. The dextran surface of the sensor chip was activated by injecting 35 μ l of 0.2M 1-ethyl-3-(3-dimethylaminopropyl)carbodiimide-HCl, 0.05M N-hydroxysuccinimide at a flow rate of 5 μ l/min. The purified eck-x (0.2 mg/ml in 10 mM sodium acetate, pH 4.0) was immobilized by two consecutive 50 μ l injections at 5 μ l/min. Unreacted binding sites were blocked by injection of 1M ethanolamine, pH 8.5. The

surface was washed overnight in running buffer (HBS, 10 mM Hepes, 150 mM NaCl, 3.4 mM EDTA, 0.005% Tween 20, pH 7.4) until a stable baseline was achieved. Typical immobilizations resulted in the establishment of

5 baselines 6000-8000 response units above original values. 50 μ l samples of various conditioned media, cultivated under serum free conditions and concentrated five- to forty-fold (centricon-10, Amicon, Danvers, MA), were injected at a flow rate of 10 μ l/min. Sample

10 response was measured at report points on the sensorgram corresponding to 20 seconds after the conclusion of each injection. The immobilized eck-x surface was regenerated between samples by 50 μ l injections of 25mM 3-(cyclohexylamino)-1-propanesulfonic acid, pH 10.4.

15 Purified eck-x immobilized on a BIAcore sensor chip was used to screen concentrated conditioned media for receptor binding activity. Binding activity was observed in several conditioned media, including those from HCT-8, SK-BR-3, and HT-29 cell lines. (see Table 1)

Table 1. Testing of cell culture supernatants by BIAcore and anti-EBP Western blot

| | <u>Cell line</u> | <u>Concentration</u> | <u>eck-x Binding Activity</u> <u>(BIAcore Response units)</u> | <u>Anti-EBP</u> <u>Western</u> |
|----|------------------|----------------------|--|-----------------------------------|
| 5 | A704 | 40X | 49 | - |
| | TE671 | 40X | 115 | - |
| | CCD18CO | 40X | 25 | - |
| | CCFSTTG1 | 40X | 35 | - |
| 10 | HCT-8 | 40X | 180 | ++ |
| | GMO-0948 | 40X | 10 | - |
| | SK-BR-3 | 40X | 270 | ++ |
| | HT-29 | 40X | 310 | ++ |
| | MDA-MB-453 | 30X | 80 | ++ |
| 15 | FF-1 | 30X | 55 | - |
| | WS-1 | 25X | 55 | - |
| | BRL-3A | 25X | 125 | - |
| | GMO1391 | 25X | 20 | - |
| | HT-1080 | 20X | 230 | + |
| 20 | AG-2804 | 20X | 170 | + |
| | BUD-8 | 20X | -10 | - |
| | AG-3022 | 20X | 175 | + |
| | HFL-1 | 20X | 15 | - |
| | LIM-1863 | 20X | 75 | - |
| 25 | PAEC | 20X | -10 | - |
| | Hos | 10X | 95 | - |
| | 33C0 | 10X | -10 | - |

30 Samples (50 μ l injections) were tested for binding to immobilized eck-x using BIAcore, as described in Example 2. Aliquots (10 μ l) of the same samples were analyzed retrospectively with rabbit anti-EBP (*E. coli*) antiserum.

EXAMPLE 3

Purification and Characterization of an eck receptor binding protein (EBP) from conditioned medium.

5

A. Immobilized eck-x receptor affinity chromatography.

Purified eck-x was dialyzed against 0.1M NaHCO₃, 0.5M NaCl, pH 8.3 and brought to a final
10 concentration of 2 mg/ml. The protein was immobilized on CNBr-activated Sepharose 4B (Pharmacia, Piscataway, NJ) at a ligand density of 1 mg eck-x per ml of gel (Kenny et al. in *New Protein Techniques*, J.M. Walker, ed. The Humana Press, Clifton, NJ. (1988)).

15

Conditioned medium from SK-BR-3 or HCT-8 cell lines was concentrated twenty fold and diafiltered against PBS (S1Y10 spiral cartridge, Amicon). The concentrate was loaded directly onto columns of immobilized eck-x (1 x 1 cm, 1mg eck-x per ml resin) at
20 a flow rate of 0.1 ml/min. The column was washed with 10 ml of PBS, followed by elution with 0.05 M sodium acetate, 0.5 M NaCl, pH 4.0. The elution pool was brought to 0.01% SDS, concentrated, and buffer exchanged against 10 mM Tris-HCl, pH 8.0 in a centricon-10
25 ultrafiltration device (Amicon). Samples were mixed with SDS-PAGE sample buffer, harvested from the centricon-10, and loaded directly onto polyacrylamide gels. Gels were stained with silver (Merrill *Meth. Enzymol.* 182, 477 (1991)) or blotted onto PVDF membranes
30 (Problot, Applied Biosystems, Foster City, CA) for N-terminal sequence analysis (Fausset et al. *Electrophoresis* 12, 22 (1991)).

An SDS-PAGE analysis of a typical run is shown in Figure 1. The pH 4.0 elution of the column, shown in
35 lane 5, displays a significant enrichment for several proteins with apparent molecular weights of 21-27 kDa.

These proteins were not detected when a similar volume of unconditioned medium was passed over the same column, indicating that the 21-27 kDa proteins were produced by the cell lines. In contrast, the higher molecular weight proteins present in the pH 4.0 elution fractions of HCT-8 or SKBR-3 conditioned medium were also observed in the unconditioned medium. These proteins represent nonspecific interactions with the column, and originate from the serum used for cell culture.

10

B. N-terminal sequence analysis of EBP.

N-terminal sequence analysis was performed on a liquid-pulse automatic sequencer (model 477, Applied Biosystems, Foster City, CA). The resulting phenylthiohydantoinyl amino acids were analyzed by on-line microbore high performance liquid chromatography (Model 123, Applied Biosystems) using a Brownlee C-18 reverse-phase column (0.21 x 25 cm). The sequencing cycles and optimization for sequence analysis of PVDF blots were based on recommendations supplied by Applied Biosystems.

N-terminal sequence analysis of the electroblotted proteins in the 21-27 kDa region of the gel revealed a single sequence (SEQ. ID. NO. 13):

25

NH₂-Asp-Arg-His-Thr-Val-Phe-Trp-[Asn]-Ser-Ser-Asn-Pro-Lys-Phe-Arg-Asn-Glu-Asp-Tyr-Thr-Ile-His-Val-Gln

A computer based homology search of the NBRF protein database (Devereux et al. *Nucleic Acids Res.* 12, 387 (1984)) resulted in the unambiguous assignment of this sequence to EBP (Holzman et al. *supra*).

30

C. Structural characterization of EBP.

Since N-terminal sequencing detected a single sequence, the multiple forms of EBP observed by SDS-PAGE

35

- 24 -

probably arise from post-translational modifications at other regions of the molecule. The sequencing yield of cycle 8 (N) was greatly diminished, indicating efficient glycosylation at this site. However, the apparent
5 heterogeneity of the protein may not be fully attributable to glycosylation differences, since digestion of rEBP with combinations of N-glycanase, neuraminidase, and O-glycanase resulted in a mixture of forms with M_r 17-19 kDa, when analyzed by SDS-PAGE.
10 Since the EBP gene codes for a protein of 22kDa (Holzman et al. *ibid*), this observation suggested that EBP might be subject to proteolytic processing.

D. Interactions of EBP with soluble eck
15 receptor.

Gel filtration analysis of the pH 4.0 eluted pool demonstrated that all of the eck-binding activity, as measured by BIAcore response, could be attributed to material eluting with apparent molecular weight of 22
20 kDa (Figure 2). SDS-PAGE analysis of the fractions from this column confirmed that EBP was co-eluted with the receptor binding activity. In separate experiments, purified EBP did not bind to BIAcore surfaces activated with the extracellular domain of the
25 kit receptor, although these surfaces could bind rSCF, the kit ligand.

E. Screening of additional cell lines for eck binding proteins.

30 Following the isolation and identification of EBP, antiserum to the protein was prepared, and a retrospective analysis of the original screening was performed (Table 1). Western blot analysis confirmed that EBP was present at high levels in three conditioned
35 media (SK-BR-3, HCT-8, and HT-29) which scored positive in the screening. Several other cell lines (AG-3022,

AG-2804, and HT-1080) scored positive, but only trace amounts of processed EBP could be detected by the Western analysis. These cell lines did produce a 28kDa protein which was detected by the anti-EBP antiserum.

5

EXAMPLE 4

Cloning, Expression and Characterization of EBP

Heat-disrupted phage from a human umbilical
10 vein endothelial cell (HUVEC) library (Clontech Laboratories, Palo Alto, CA) were used as a template for amplification of the human EBP gene by polymerase chain reaction (PCR) (Saiki et al. *Science* 230, 1350 (1985); Mullis et al. *Cold Spring Harbor Symp. Quant. Biol.* 51,
15 263). Primers were designed based on the published nucleic acid sequence of EBP (Holzman et al. *ibid*) to yield PCR fragments that could be inserted into either *E. coli* or CHO cell expression vectors.

20

A. Cloning of EBP for *E. coli* Expression

A gene for *E. coli* expression of the full length form of EBP was generated by PCR using oligonucleotide primers 386-4 and 386-5 as shown below:

25 386-4) 5' AAG CAT ATG GAT CGC CAC ACC GTC TTC TGG 3'
(SEQ. ID. NO. 2)
386-5) 5' GAA GGA TCC TTA TCA CGG GGT TTG CAG CAG CAG
AA 3' (SEQ. ID. NO. 3)

30 This form lacked the signal peptide and included an initiator methionine as well as restriction sites necessary for cloning into the expression plasmid pCFM1156 (Fox et al. *J. Biol. Chem.* 263, 18452 (1988)). A 10 µl aliquot of the λ gt11/HUVEC library (Clontech)
35 was heat treated at 70° C for 5 minutes then quick-cooled on wet ice. The disrupted phage were used as the

template for a PCR reaction containing 300 picomoles each of primers 386-4 and 386-5, 1X TaqI polymerase buffer (Promega, Madison, WI), 0.77 mM of each dNTP, and 2.5 units of TaqI polymerase (Promega) in a volume of 100 μ l. The product of this reaction was extracted with phenol/chloroform, ethanol precipitated, resuspended in 20 μ l of distilled water and then digested with the restriction endonucleases NdeI and BamHI (Boehringer Mannheim, Indianapolis, IN). This fragment was ligated into the plasmid vector pCFM1156 which had been digested with the same two enzymes and transformed into the *E. coli* host strain FM5 (A.T.C.C. No. 53911). When transformed cells were temperature shifted from 30°C to 42°C, EBP was expressed at high levels.

A gene designed to express the 150 amino acid form of EBP in *E. coli* was constructed as described for the full-length gene except that oligonucleotide 469-11 was used in PCR instead of 386-5. Oligonucleotide 469-11 has the sequence:

5' GAAGGATCCCTATTATGCTGCAAGTCTTCTCCTG 3'
(SEQ. ID. NO. 4)

B. Cloning of EBP for CHO cell expression

Total RNA was isolated from the cell line SK-BR-3, and used to prepare cDNA. Three μ g of total RNA was mixed with 3 μ g of random primer (Gibco BRL, Gaithersburg, MD), incubated at 65°C for 5 min, then cooled briefly on ice. The RNA-primer mixture was then used in a cDNA reaction which consisted of 50 mM Tris-HCl (pH 8.3), 75 mM KCl, 3 mM MgCl₂, 10 mM DTT, 125 μ M of each dNTP (dATP, dCTP, dGTP, dTTP), 200 units of reverse transcriptase (Superscript, BRL), in a final reaction volume of 20 μ l. The reaction was incubated at 37°C for 1 h.

Two oligonucleotides were synthesized and used with the SK-BR-3 cDNA to amplify the EBP coding region by PCR.

5 386-2) 5' GAA TTC AAG CTT CAG GCC CCG CGC TAT GGA G 3'
(SEQ. ID. NO. 5)

386-3) 5' GAA TTC TCT AGA TCA TCA CGG GGT TTG CAG CAG
CA 3' (SEQ. ID. NO. 6)

10 The PCR contained 1 μ l of the cDNA reaction, 500 ng of both of the above oligonucleotides, 10 mM Tris-HCl (pH 8.3), 50 mM KCl, 200 μ M of each dNTP, and 1.25 units of Taq polymerase (Perkin Elmer Cetus, CA). DNA was amplified for 35 cycles (94°C for 30 s, 50°C for
15 1 min, 72°C for 1 min), extracted 1 time with phenol, 1 time with phenol-chloroform, precipitated, pelleted by microcentrifugation, and digested with the restriction enzymes Hind III and Xba I (Boehringer Mannheim). The DNA was gel-purified (Geneclean II, Bio 101, La Jolla,
20 CA) and ligated to the plasmid pDSR α 2 (deClerck et al., *ibid*) which had been previously digested with the same restriction enzymes. The ligated DNA was transfected into competent HB101 bacteria (BRL), and plasmid DNA was isolated (Qiagen, Chatsworth, CA). The DNA sequence was
25 confirmed by the dideoxy chain termination reaction (Sanger et al. *Proc. Natl. Acad. Sci. USA* 74 5463 (1977)) on double-stranded plasmid DNA using synthetic primers that corresponded to the EBP DNA sequence.

Culture supernatants from CHO cells
30 transfected with the EBP gene displayed eck-x binding activity on the BIAcore, and EBP could be recovered from the supernatants by immobilized eck-x receptor affinity chromatography. Untransfected CHO cells, or CHO cells transfected with a EBP gene containing an internal
35 deletion, displayed no receptor binding activity.

C. Purification of recombinant EBP from
E. coli and CHO cells

Recombinant EBP was purified from CHO cell culture supernatants by immobilized eck-x receptor affinity chromatography as described in Example 3A. The purified EBP was dialyzed vs. PBS with either 5 mM CHAPS (for structural analysis and crosslinking studies) or 0.5 mg/ml BSA (for phosphorylation studies). The CHO cell-derived EBP purified by receptor affinity chromatography contained two major bands, as well as a few minor bands (Figure 1B).

Recombinant EBP from CHO cells was also purified by conventional chromatography. The CHO cell culture supernatant was concentrated and diafiltered against 10 mM Tris, pH 8.5 and applied to an anion exchange column (Q-Sepharose, Pharmacia-LKB). The column was eluted with a linear gradient of NaCl in 10 mM Tris-HCl, pH 8.5. Analysis of the fractions by western blotting showed that the two major EBP bands had been separated from one another. Separate pools were made of fractions containing the major EBP bands, and the pools were further purified by gel filtration chromatography (Superdex-75, Pharmacia-LKB).

Recombinant EBP from *E. coli* was purified by the following method. Cells expressing the EBP1-150 or EBP1-187 genes were suspended in 10 mM Tris-HCl, pH 7.4 and lysed using a French press. The lysate was centrifuged in a J6-B (JS-4.2 rotor) at 4000 rpm for 30 min. The insoluble pellets (containing either unfolded EBP1-150 or EBP1-187) were saved for further processing. The pellets were suspended in 2% sodium deoxycholate, 5 mM EDTA, 10 mM Tris-HCl, pH 8.5, and mixed for 30 minutes at 4°C. The suspensions were centrifuged as above, and the supernatants discarded. The insoluble pellets were suspended in 10 mM Tris-HCl, pH 7.4, mixed, and centrifuged as above. The insoluble

- 29 -

pellets were dissolved in 2% sarkosyl, 10 mM CAPS, pH 10 in order to solubilize EBP1-150 or EBP1-187. CuSO₄ was added to a final concentration of 50 μ M, and the mixtures were stirred overnight at 4°C, then treated
5 with Dowex 1X4 resin in order to remove the detergent.

SDS-PAGE analysis revealed that a large proportion of EBP1-150 or EBP1-187 had oxidized and was monomeric. However, gel filtration analysis of EBP1-187 showed that the protein behaves as a high molecular
10 weight noncovalent aggregate. In contrast, gel filtration analysis indicates that the refolded EBP1-150 behaves as a monomer or dimer.

EBP1-187 and EBP1-150 produced in *E. coli* were tested for binding to immobilized eck-x by BIAcore as
15 described in Example 2. The EBP1-187 aggregate bound poorly, if at all, to the eck-x surface. Refolded EBP1-150 demonstrated high affinity for eck-x surfaces on the BIAcore.

Alternatively, the following procedure was
20 used to re-fold EBP1-150 expressed in *E. coli*. Cell paste was suspended in 9 volumes (v/w) of cold Super-Q water. The suspended cell paste was lysed using a Gaulin homogenizer at a pressure of 9,000 psi. The lysate was immediately centrifuged at 3,500 X G, 4°C for 30
25 minutes. The supernatant was discarded and the pellet, containing EBP inclusion body, was saved. The pellet was suspended in 10 volumes (v/w) of 8M urea, 0.1M Tris, pH 8.5, and stirred for one hour. Centrifugation was then performed to remove the insoluble fraction.
30 Refolding was effected by two stepwise dilutions of the soluble inclusion body. First, the inclusion body was diluted into 10 volumes (v/w) of 3M urea, 0.1M Tris, pH 8.5, containing 0.0005% CuSO₄ as a oxidizing agent, at 4°C while stirring overnight. This material was diluted
35 with 3 volumes (v/v) of 20mM Tris, pH 9.2, and was incubated for 24 hrs with gentle stirring.

Centrifugation was performed at 15,000 X G, 4°C for 30 minutes to remove precipitate.

The supernatant was then applied into Q-Sepharose Fast Flow column and washed with five column
5 volumes of 20mM Tris, pH 9.2. The column was eluted with a linear gradient of NaCl from 0-0.5M in 20mM Tris, pH 9.2. Fractions containing EBP were pooled, concentrated, and subjected to Superdex-75 chromatography. The EBP was eluted with 1X PBS.

10 The resulting purified EBP had a specific activity that is 30-40% of purified CHO derived EBP as measured by its ability to bind to immobilized eck-x in a BIAcore assay. The *E.coli* produced EBP refolded and purified by this procedure induced the phosphorylation
15 of eck localized on cellular surfaces.

D. Characterization of recombinant EBP from *E. coli* and CHO cell expression

Recombinant EBP, purified by receptor
20 chromatography from CHO cell culture supernatants, or by RP-HPLC from *E. coli* was digested with trypsin and analyzed by RP-HPLC. Although the C-terminal peptide (aa 155-187) was recoverable from the EBP¹⁻¹⁸⁷ gene expressed in *E. coli*, it could not be detected in the
25 mammalian derived recombinant protein. Carboxypeptidase digestion of the purified CHO EBP indicated that the only detectable C-terminal sequence was -lys-arg-leu-ala-ala-COOH (SEQ. ID. NO. 12), indicating a terminus at amino acid 150.

30

E. Alternative Forms of EBP

EBP isolated from SK-BR-3 cell line as described in Example 3 migrated on SDS-PAGE in the range of 21-27 kDa (see Figure 1A). Recombinant EBP in CHO
35 cell supernatants existed as two major species and a few minor bands after eck-x chromatography (Example 4 and

- 31 -

Figure 1B). Further characterization of the different molecular weight forms of CHO-derived EBP was undertaken. Purification of recombinant EBP from CHO cell supernatants revealed two bands of 22 and 24 kDa and a third minor band of 27 kDa (see Figure 3).
5 Treatment of purified EBP with glycosidases did not change the relative migration of these bands suggesting that they did not arise simply by variation in N- or O-linked carbohydrate. C-terminal sequencing previously
10 revealed the 22kDa band as a polypeptide of 150 amino acids designated EBP¹⁻¹⁵⁰. The 24 kDa band was found to be 159 amino acids long as evidenced by C-terminal sequencing. This form was designated EBP¹⁻¹⁵⁹.

CHO cells expressing EBP were studied for the
15 presence of membrane-bound forms of EBP. The recombinant CHO cell line 36.44 was established by transfection of CHO⁻ cells with the plasmid pDSR α -EBP. Cells were grown in suspension media using DMEM:F12 media supplemented with 1X non-essential amino acids and
20 1X penicillin, streptomycin, glutamine with 10% heat inactivated dialyzed fetal bovine serum. Aliquots of 10⁶ cells were treated with 4 μ g/mL phospholipase C (Calbiochem, La Jolla, CA) in 1mL phosphate buffered saline at 37°C for various times. Cells were pelleted
25 at 14,000 RPM for 1 minute. Supernatants were removed for analysis. Cell pellets were lysed in RIPA buffer (150 mM NaCl; 1% NP-40; 0.5% deoxycholate; 50 mM Tris-HCl pH 8.0; 0.1% SDS; 1.74 μ g/mL PMSF; 1ng/mL each of aprotinin, pepstatin and leupeptin; 18.4 μ g/mL
30 orthovanadate). Samples were applied to a 14% Tris-Glycine gel, blotted to a PVDF membrane and probed with a rabbit anti-EBP polyclonal antibody. Figure 4 shows that EBP was released into the supernatant in the presence of phospholipase C. These experiments
35 suggested that the 27 kDa form of EBP had a glycopospholipid anchor.

EXAMPLE 5
EBP Analogs

5 In addition to the different forms of
recombinant EBP made from the full-length EBP gene,
analogs of EBP were constructed having varying
polypeptide lengths. In particular, EBPs having 167,
171 and 180 amino acids were constructed as follows.
10 Oligonucleotides 421-12, 421-13 and 421-14 were
synthesized for use as PCR primers to introduce
termination codons following amino acid 180, 171 and
167, respectively. PCR reactions were done as described
in Example 4B using each of those primers and the pDSR α -
15 EBP plasmid and oligonucleotide 386-2.

421-12 5'-GAATTCTCTAGATTATCATGGAAGGAGCAGCACAGTCCAG-3'
(SEQ. ID. NO. 14)

421-13 5'-GAATTCTCTAGATTATCATGGGAAGAGGCGTGGGGCAGC-3'
20 (SEQ. ID. NO. 15)

421-14 5'-GAATTCTCTAGATTATCATGGGGCAGCACTGTGACCGATGC-3'
 (SEQ. ID. NO. 16)

 The resulting analogs were expressed in CHO
25 cells transfected with the altered DNA sequences using
procedures described for the expression of EBP. Cells
were grown to confluence in the presence of serum
whereupon the media was switched to serum-free and
allowed to accumulate. At 48 hours the conditioned
30 medium was collected and the adherent cells were lysed.
Aliquots of the conditioned media and lysates were
fractionated by polyacrylamide gel electrophoresis and
subjected to Western blotting. EBP¹⁻¹⁸⁷ and EBP¹⁻¹⁸⁰
displayed a similar distribution of protein reacting
35 with the antibody in lysates and supernatants. Cells
expressing EBP¹⁻¹⁷¹ and EBP¹⁻¹⁶⁷ had accumulation of EBP in

the supernatants, but not in the lysates. EBP analogs are analyzed for binding to eck-x by BIAcore as describe in Example 2 and for phosphorylation activity of eck receptor as described in Example 6.

5

EXAMPLE 6

Interactions of recombinant EBP with the eck receptor

A. Crosslinking studies.

10 CHO-cell derived EBP was radiolabelled with ^{125}I as described below for use in crosslinking and binding studies. Five or 10 μg of EBP in 0.1M sodium phosphate (NaPO_4 , pH 8.0) was added to 5 mCi of dried ^{125}I -Bolton-Hunter reagent (NEN, Boston, MA) in a final
15 volume of 50 μl or 100 μl , and the tube was incubated at 4°C for 1 h. The reaction was terminated by addition of 0.3 ml of 0.2M glycine in 0.1M NaPO_4 , followed by incubation at 4°C for 5 min. Labeled protein was separated from unincorporated reagent by gel filtration
20 chromatography on a 10 ml PD10 column containing Sephadex G-25 M (Pharmacia) equilibrated with 0.1M NaPO_4 - 0.25% gelatin. Specific activity of the ^{125}I -EBP ranged from 4 to 19 cpm/pg.

Crosslinking of EBP to either LIM 2405 (a cell
25 line naturally expressing the eck receptor) or CHO 19.32 (Chinese hamster ovary cells transfected with a clone of the full length eck receptor) was carried out as follows. CHO cells were grown in suspension to a density of approximately 5×10^5 cells/ml in media.
30 LIM2405 cells were grown in RPMI 1640 media containing 5% FCS, 1 $\mu\text{g}/\text{ml}$ insulin, 1 $\mu\text{g}/\text{ml}$ hydrocortisone, 10 μM thioglycerol and 2 mM L-glutamine to approximately 90% confluency in T-175 flasks and removed by scraping for use in the crosslinking studies. Cells were spun down
35 and resuspended in PBS to give a single cell suspension. For each crosslinking reaction, 2×10^6 cells were mixed

with approximately 20 ng of ^{125}I -EBP in a total volume of 1 ml. This mixture was incubated at 4°C for 1 h to allow binding of EBP to cell surface receptors before the addition of 20 μl of 10mM disuccinimidyl suberate (DSS) as a crosslinking agent. Cells were then washed three times in binding buffer, collected by centrifugation, and the amount of radioactivity incorporated into the cell pellets was counted to assess the degree of crosslinking. The cells were then lysed by treatment with 100 μl PBS, 1 mM EDTA, 0.5% NP-40, 1 mM phenylmethylsulfonyl fluoride (PMSF, Sigma, St. Louis, MO) for 10 min at 4°C . The insoluble material was removed by centrifugation and the soluble fraction containing the receptor/ligand complex was collected. These samples were either run directly on SDS-PAGE or first immunoprecipitated with an antibody directed against the C-terminal portion of the eck receptor (Lindberg et al. *supra*). Competition with either unlabeled EBP or an irrelevant protein (FGF) was carried out by mixing the competitor with the labeled EBP prior to addition to the cells.

As shown in Figure 5, ^{125}I -rEBP could be crosslinked to CHO 19.32 cells (lane 1) but not to the untransfected cells (lane 2). Crosslinking resulted in the detection of a 145 kDa protein, as well as higher molecular weight forms which may represent receptor dimers or higher order complexes. Unlabelled rEBP at 50-fold molar excess was able to compete for binding and crosslinking (lane 3). In separate experiments, recombinant fibroblast growth factor at concentrations of 1 $\mu\text{g}/\text{mL}$ had no effect on rEBP crosslinking. Similar crosslinking results were obtained for the LIM 2405 cell line.

B. Binding studies.

To measure association kinetics, CHO 19.32 cells (2×10^6 cells/ml) were incubated with 3.8 nM ^{125}I -EBP in PBS-BSA (1mg/ml), at 0°C . Aliquots were removed, and cell-bound ^{125}I -EBP was determined by centrifugation through sucrose gradients. Nonspecific binding was measured from parallel reactions containing 380 nM unlabelled EBP.

Equilibrium binding constants were determined by incubating CHO 19.32 or LIM 2405 cells (0.5×10^6 cells/ml) with varying amounts of ^{125}I -EBP at 0°C for 1 h, bound EBP was determined as above, and the data was analyzed by the method of Scatchard (*Annal. N.Y. Acad. Sci.* 51, 660 (1949)). Nonspecific binding was determined from parallel reactions containing a 50 fold excess of unlabeled EBP.

A Scatchard analysis of the steady-state binding of ^{125}I -rEBP to LIM2405 cells revealed that there was apparently a single class of receptors on the cell surface with a K_d of $2.8 \times 10^{-8} \text{ M} \pm 0.3 \times 10^{-8}$. On average, the LIM2405 cells contained 1.3×10^6 EBP receptors at the cell surface. BIAcore analysis of EBP binding to immobilized *eck*-x surfaces resulted in an estimated K_d of $2.4 \times 10^{-8} \text{ M} \pm 0.4 \times 10^{-8}$.

C. $p130^{eck}$ autophosphorylation studies.

The LIM 2405 colorectal carcinoma cell line (Whitehead et al. *Immunol. and Cell Biol.* 70, 227 (1992)) was maintained in RPMI 1640 containing 5% FBS, 1 $\mu\text{g/ml}$ insulin, 10 $\mu\text{g/ml}$ hydrocortisone and 10 μM α -thioglycerol, and subpassaged by trypsinization and dilution (1:5) into fresh media. Prior to assay 2.5×10^5 LIM 2405 cells were seeded into 6-well dishes (Falcon # 3046) and incubated for 24 hr at 37°C . The media was discarded and replaced with serum-free RPMI 1640 containing 0.03% BSA, 1 $\mu\text{g/ml}$ insulin, 10 $\mu\text{g/ml}$

hydrocortisone and 10 μ M α -thioglycerol, then incubated for 12-18 hr. In some experiments the cell cultures were labelled with 32 P-orthophosphate (2 mCi/ml) in phosphate-free RPMI 1640 (Flow) for 2-3 hr prior to
5 treatment. Growth factor stock solutions were prediluted at varying concentrations into 2.0 ml of serum-free media, then warmed to 37°C. Cell cultures were removed from the incubator, and the supernatant media discarded. Treatments were promptly added and the
10 cell cultures incubated at 37°C for 10-15 min. The cultures were then removed from the incubator, placed on ice, and the culture supernatant aspirated.

The treated cell cultures were chilled to 0°C then washed once with ice-cold PBS (GIBCO). The
15 residual PBS was aspirated and the cells were lysed by the addition of 1.0 ml of ice-cold RIPA buffer (10 mM sodium phosphate, pH 7.4, 150 mM sodium chloride, 0.1 % sodium dodecyl sulfate, 1% NP-40, 1% deoxycholate, 1% Trasylol, 2 mM EDTA, 50 mM sodium fluoride and 100 mM
20 sodium orthovanadate). After a 10 min incubation the lysates were transferred to 1.5 ml tubes and clarified by centrifugation for 30 min at 10,000 X g. The clarified lysate supernatants were transferred to new tubes and immunoprecipitated with 1.0 μ g/ml of affinity
25 purified rabbit anti-Eck C-terminal domain antibody for 2 hr at 0°C. Immune complexes were adsorbed to Protein-G Sepharose beads (Pharmacia) at 4 °C for 30 min, washed twice with ice-cold RIPA buffer, once with 0.1 M Tris-HCl, pH 8.0, containing 0.5 M LiCl, and once with RIPA.
30 The resulting immunoprecipitates were solubilized with SDS-PAGE sample buffer and stored for further analysis.

The anti-eck immunoprecipitates from treated and untreated LIM 2405 cell lysates were resolved on 7.5% polyacrylamide gels as previously described (Boyle
35 et al. *Meth. Enzymol.* 201, 110 (1991)). After electrophoresis, the gels were electroblotted (Kamps

Meth. Enzymol. 201, 110 (1991)) onto Immobilon P (Millipore) and the blots were incubated for 1 hr in Tris-buffered saline containing 0.1 % Tween-20 (TBST) and 5% BSA to block non-specific binding sites on the
5 membrane. Primary antibodies, either anti-phosphotyrosine antibody (4G10, UBI, Lake Placid, NY), or anti-*ec*k C-terminal, were diluted to 1.0 µg/ml in TBST containing 3% BSA, 1% ovalbumin and incubated with the blots for 1 hr at room temperature. After this, the
10 blots were rinsed with TBST, then washed once for 10-15 min, then twice for 5 min, each with TBST. The blots were then incubated with a 1:5000 dilution of secondary antibody coupled to horseradish peroxidase (Amersham, Arlington Heights, IL) in TBST alone for 20-30 min, then
15 washed as before using TBST. Immune complexes were detected by chemiluminescent exposure (ECL, Amersham) to Kodak X-OMAT X-ray film at room temperature for 0.5-5 min.

Eck receptor immunoprecipitates from
20 ³²P-labelled LIM 2405 cells were resolved by SDS-PAGE, and the gel dried directly without fixation. After exposure to X-ray film the labelled *ec*k receptor band was isolated and phosphoamino acid content determined as described (Boyle et al. Meth. Enzymol. 201, 110 (1991))

25 CHO cell-derived rEBP stimulated *ec*k receptor phosphorylation in intact LIM 2405 cells in a dose-dependent manner, with an optimal concentration between 100 ng/ml and 1 mg/ml (Figure 6, upper panel). There also appeared to be a modest dose-dependent decrease in
30 the total cellular *ec*k protein levels (Figure 6, lower panel), suggesting down regulation of the receptor after exposure to soluble EBP. Treatment of LIM 2405 cells with EBP does not result in spurious phosphorylation of the EGF receptor, nor does EGF treatment induce *ec*k
35 phosphorylation. Furthermore, when total cellular protein from LIM 2405 cells treated with rEBP was

analyzed, the only induced phosphoprotein is a Mr 130 kd polypeptide that corresponds to the mature eck receptor.

rEBP1-150 from *E. coli* was also assayed for autophosphorylation of the eck receptor on LIM 2405 cells following the procedure used for CHO-cell derived rEBP. Upon treatment of cells with the same quantities of CHO-derived rEBP and *E. coli* derived EBP1-150, it was observed that both forms of recombinant EBP were active in inducing phosphorylation.

10

EXAMPLE 7

Formulation of Recombinant EBP

Measuring the ability of EBP to bind to the immobilized soluble extracellular domain of eck using BIAcore, it was determined that dilute solutions of purified EBP rapidly lost the ability to bind to the eck receptor unless formulated with a protective agent such as a detergent. Recombinant CHO EBP diluted into PBS to 100 µg/ml and incubated for 2 hours at 3°C lost approximately 50% of its eck binding activity. This loss of activity can be avoided by formulating the EBP in a detergent such as 1mM CHAPS, 0.1% NP-40, 0.1% tween 20, 0.1% triton-X 100, or 0.1% tween 80. (see figure 7). The loss of eck binding activity in diluted EBP can also be avoided by incubating the protein with other protein carriers such as fetal calf serum.

The eck binding activity of at EBP 2-5mg/ml kept in detergent solutions is stable for at least one week at 3°C, but protein solutions in the 10-500µg/ml range will lose activity if stored at -20°C, or if they are subjected to multiple freeze thaw cycles.

30

EXAMPLE 8

Expression of EBP and eck
receptor in tissues and cell lines

5 Expression of EBP has been studied at the mRNA
level in various rat tissues and organs using procedures
described in Lindberg et al., supra. EBP is expressed
most highly in the lung, intestine, liver, ovary and
kidney. Expression was also detected at lower levels in
10 muscle, stomach, and brain.

 Expression studies have been done for both EBP
and the eck receptor in cell lines. EBP expression was
tested for by immunoblotting cell supernatants in a
Western analysis with affinity purified anti-human EBP
15 monoclonal antibodies. As shown in Table 2, EBP is
found in many carcinoma cells. eck expression was
tested for by several methods, including immunoblotting
of whole cell lysates and immunoprecipitation with anti-
eck antibody from cell lysates. (Lindberg et al.,
20 supra) The results in Table 2 show that eck is
expressed in many cell lines of epithelial origin, and
in addition, is found in fibroblasts and melanoma cell
lines.

25

TABLE 2

| | | |
|----|------------------------------|-------------------------|
| 5 | Cell lines that express EBP: | |
| | Cell line | Cell type |
| 10 | CaCo2 | Colon adenocarcinoma |
| | FADU | Squamous carcinoma |
| | T47D | Breast carcinoma |
| | MDAMD361 | Breast adenocarcinoma |
| | THP-1 | Monocytic leukemia |
| 15 | SKBR3 | Breast adenocarcinoma |
| | CaOV4 | adenocarcinoma |
| | MDAMB453 | Breast adenocarcinoma |
| | Caki1 | Kidney carcinoma |
| | HBL100 | Breast |
| | HT29 | Colon adenocarcinoma |
| 20 | JEG1 | Choriocarcinoma |
| | 293 | Embryonic kidney |
| | A704 | Kidney adenocarcinoma |
| | Caki2 | Kidney adenocarcinoma |
| | CaOV3 | Ovarian adenocarcinoma |
| 25 | SKOV3 | Ovarian adenocarcinoma |
| | A172 | Glioblastoma |
| | A431 | Epidermal carcinoma |
| | BSC1 | Kidney |
| | BT20 | Breast carcinoma |
| 30 | PC3 | Prostate adenocarcinoma |
| | JAR | Choriocarcinoma |
| | A498 | Kidney carcinoma |
| | LNCaP | Prostate adenocarcinoma |
| | BT474 | Breast carcinoma |
| 35 | SW480 | Colon adenocarcinoma |
| | SW620 | Colon adenocarcinoma |
| | MCF7 | Breast adenocarcinoma |
| | T24 | Bladder carcinoma |
| | 5637 | Bladder carcinoma |
| 40 | Du145 | Prostate carcinoma |
| | SKNSH | Neuroblastoma |
| | L929 | Connective tissue |
| | G401 | Kidney Tumor |

TABLE 2 (Con't)

| | | |
|----|------------------------------|-----------------------|
| 5 | Cell lines that express eck: | |
| | Cell line | Cell type |
| | THP-1 | Monocytic leukemia |
| 10 | CCD11Lu | Lung |
| | HT29 | Colon adenocarcinoma |
| | SKOV3 | Ovarianadenocarcinoma |
| | A172 | Glioblastoma |
| | A431 | Epidermal carcinoma |
| 15 | JAR | Choriocarcinoma |
| | GM4312A | Fibroblast |
| | Wi38 | Lung |
| | UT7 | Premegakaryocyte |
| | CHOK1 | Ovary |
| 20 | HS249T | Melanoma |
| | M14 | Melanoma |
| | NIH3T3 | Fibroblast |

EXAMPLE 9

Biological Activities of EBP

A. Activity of EBP in Rat Wound Chamber Assay

5 The effects of recombinant CHO-derived and E.coli derived EBP on granulation tissue formation in subcutaneously implanted wound chambers in rats was studied.

Male Sprague-Dawley specific pathogen free
10 rats (300-350g; Charles River Breeding Laboratories, Inc.) were used for this study. Rats were anesthetized with sodium pentobarbital (50 mg/kg body weight) by intraperitoneal injection. Using aseptic surgical technique, a 3 cm midline incision was made on the
15 dorsal surface of the rat. A single pocket was formed under the panniculus carnosus by blunt dissection on one side of the animal. A 3 cm long x 1 cm diameter sterile stainless steel wire mesh cylinder was then inserted subcutaneously. The wound chambers used were similar to
20 those described by Schilling et. al. (*Surgery* 46, 702-710 (1959)) and utilized by Hunt et. al. (*Am. J. Surg.* 114, 302-307 (1967)) as wound healing models. The incision was closed with wound clips. The rats survived the operation well with no evidence of postoperative
25 discomfort. Beginning 3 days after wound chamber implantation, the rats were randomly divided into 5 groups. At this time daily injections of 1) 10 µg CHO-derived EBP, 2) 1 µg CHO-derived EBP, 3) 8 µg E.coli-derived EBP, 4) 5 µg recombinant platelet derived growth
30 factor (PDGF), or 5) 0.1 ml sterile PBS and 1 mM CHAPS were begun and continued for a total of 9 days. The injections were made directly into the wound chamber through a silicone septum at the outer edge of the chamber. Twelve days after chamber implantation, the
35 rats were sacrificed by CO₂ asphyxiation. Immediately after sacrifice, the chambers were removed surgically

and carefully opened. The enclosed granulation tissue was then weighed, and stored at -70°C for future processing.

Granulation tissue samples were thawed and
5 homogenized with a Polytron homogenizer in 2 ml of ice-cold distilled water for approximately 1 minute. Next, 2 ml of ice-cold 10% trichloroacetic acid was added to the homogenate and incubated at 4°C for 1 hour. The TCA-precipitated samples were centrifuged (500g, 10
10 minutes) at 4°C , washed once with 2 ml of ice-cold 5% TCA, and finally washed with 2 ml of ice-cold 95% ethanol containing 50 mM sodium acetate. Samples were defatted twice with 2 ml of ethanol:ether (3:1, v/v) at 20°C . After each defatting procedure, samples were
15 centrifuged (500xg, 10 minutes) and the supernate discarded. The pellet was then dissolved in 1N sodium hydroxide and brought up to a volume of 10 ml.

Total protein was determined by taking an aliquot of the solubilized granulation tissue and
20 assaying the sample according to the method of Bradford (Anal. Biochem. 72, 248-251 (1976)) Bovine serum albumin (Sigma Chemical Co., St. Louis, MO) was used for a protein standard curve.

Total DNA content was determined as deoxy-
25 ribose by the colorimetric method of Burton (Biochem. J. 62, 315 (1956)). Briefly, a 1 ml aliquot of the solubilized sample (in N NaOH) was neutralized with the addition of 0.5 ml of 2 N HCl. A 1 ml aliquot of the neutralized solution was extracted in 10% perchloric
30 acid at 90°C for 15 minutes. A 1 ml portion of the final extract was added to 2 ml activated diphenylamine (Sigma Chemical, St. Louis, MO) reagent and absorbance at 600 nm was measured after overnight incubation at room temperature. Hydrolyzed calf thymus DNA (Sigma)
35 was used to construct the standard curve. The DNA content was measured as a rough index of the number of

cells in the wound chamber, with the realization that cell type and cell cycle status also influence DNA content.

Total glycosaminoglycans (GAGs) were determined using chondroitin sulfate as a standard. A spectrophotometric assay for GAGs was run utilizing a change in absorption spectrum of the dye 1,9- dimethyl methylene blue (Farndale et al. Conn. Tiss. Res. 2, 247-248 (1982)).

Total collagen content was determined as hydroxyproline (an index of collagen content) after hydrolysis of the solubilized granulation tissue in 6N HCl at 110°C for 24 hours. Aliquots of 200 µl sample hydrolyzate were dried down, reconstituted in 200 µl of buffer and analyzed for hydroxy-L-proline by amino acid analysis using a Beckman 6300 amino acid analyzer. Quantitation was done using an external standard of hydroxy-L-proline (Sigma).

The data was analyzed by one-way analysis of variance. Significant differences were then analyzed comparing individual group means using a two-tailed unpaired student's t test. Statistical significance was defined as $p < 0.05$. All values are expressed as mean \pm SEM.

CHO-derived rEBP at a dose of 10 µg per chamber per day for 9 consecutive days and rPDGF at a dose of 5 µg per day (x 9 days) both significantly increased the wet weight, total protein, total DNA and total GAG content of the chamber granulation tissue as compared to vehicle-treated (PBS and 1 mM CHAPS) control rats (see Table 3). All chambers were harvested 12 days after implantation. This timepoint is at the peak of granulation tissue formation and at the early stages of collagen formation. CHO-derived rEBP at a dose of 1 µg per chamber per day showed a significant increase in granulation tissue wet weight and GAG content over

vehicle treated control rat chambers. However, there were no significant differences against control in the total protein, DNA, and hydroxyproline content for the 1 µg rEBP dose.

- 5 The accumulation of collagen is probably the single most important factor contributing to wound strength. PDGF treated chambers showed an 82% increase in hydroxyproline content (and therefore collagen synthesis) over control chambers. CHO-derived rEBP
- 10 showed a 21% increase in hydroxyproline at 1 µg/chamber/day, and a 35% increase in hydroxyproline at 10 µg/chamber/day, although these increases were not statistically significant.

TABLE 3
Effects of CHO-Derived EBP on Granulation
Tissue Formation in Wound Chambers in Rats

| TREATMENT | WET WEIGHT (mg) | TOTAL PROTEIN (mg) | DNA (μ g) | HYDROXY - PROLINE (μ g) | TOTAL GYLCOSAMINO - GLYCANS (μ g) | CHANGE IN BODY WEIGHT (g) |
|--------------------|-----------------------|--------------------------|-------------------|------------------------------------|---|---------------------------------|
| Control | 158.6 \pm 17.9 | 2.76 \pm 0.27 | 153 \pm 20 | 263.5 \pm 29.1 | 383.3 \pm 41.5 | +53.8 \pm 5.4 |
| PDGF 5ug | 417.4 \pm 81.8** | 7.46 \pm 1.52** | 356 \pm 64** | 478.4 \pm 85.9* | 725.2 \pm 104.4** | +45.4 \pm 2.8 |
| CHO-EBP 10 μ g | 398.2 \pm 70.9** | 7.15 \pm 1.23** | 650 \pm 163* | 354.5 \pm 63.7 | 627.9 \pm 92.4* | +50.3 \pm 5.2 |
| CHO-EBP 1 μ g | 238.0 \pm 24.1* | 3.88 \pm 0.44 | 232 \pm 41 | 318.7 \pm 31.7 | 589.2 \pm 68.4* | +48.5 \pm 4.9 |

All Values are Mean \pm SEM

*p<0.05 by two-tailed unpaired Student's t test vs. control group

**p<0.01 by two-tailed unpaired Student's t test vs. control group

B. Activity of EBP in Murine Hematopoiesis

Unfractionated bone marrow suspensions from BDF mice were plated into serum free culture medium (Iscove's modified Dulbecco's medium) in 0.3% agarose and incubated at 37°C, 5% CO₂ for ten days at a cell concentration of 1X10⁵/ml in 96 well plates. Total volume per cell was 50 µl. EBP and other growth factors were added in the amounts indicated and colonies were scored at the tenth day of incubation. The results are shown in Figure 8.

EBP at 1 µg/ml could potentiate murine IL-3 dependent murine CFU-C formation about 2-fold compared to IL-3 alone. CFU-C represents CFU-G, CFU-GM and CFU-M. EBP alone showed no stimulation of CFU-M or BFU-E/CFU-E.

C. Activity of EBP in Colon Crypt Assay

Colons from five (BDF) mice were removed and crypts isolated using a non enzymatic (EDTA) extraction method. Briefly, colons are washed and allowed to sit for 20 min. in a solution of PBS containing .04% sodium hypochlorite. Crypts are isolated by incubating the tissue for 1 hour at 37°C in a solution of PBS containing 3mM EDTA and 0.5 mM DTT. Crypts are then subjected to pancreatin digestion (0.2% in PBS) for 90 min. at 37°C in order to obtain a single cell suspending. Cells are washed in PBS, counted and viability determined by trypan blue exclusion (85% in this experiment). Cells are then plated in a top layer of 0.37% Sigma low melt agar onto a bottom layer of 0.5% agar. The RPMI media used in the agar includes the presence of 1X ITS (insulin, transferrin, and selenium, Gibco). Incubations were done in the presence of 1% fetal calf serum (FCS) and the indicated growth factors at the following concentration: TGFα, 50ng/ml; bFGF, 60ng/ml; EBP, 500ng/ml. Control incubations lacked

growth factors and/or FCS. Each of the various culture conditions was performed in triplicate and scored every several days.

Positive results were obtained after crypt
5 cells were incubated with 1% FCS and EBP or 1% FCS and bFGF. In both conditions, the clusters of cells were large and the individual cells within the clusters appear healthy. In some cases the clusters were crypt-like shaped. When both EBP and bFGF were added together
10 with FCS, fewer and smaller clusters appeared compared to when either growth factor was added alone in the presence of 1% FCS. Initially, the combination of EBP and bFGF appeared to be inducing cell growth but this stimulation in growth was short lived. In the plates
15 with EBP alone (no serum) there were occasional large clusters, however these were looser, the cells were larger and roughly half the cells were nonviable within the cluster.

These results suggest that EBP is involved in
20 the proliferation, differentiation or reformation of colon crypt cells.

TABLE 4
Activity of EBP in Colon Crypt Assay

| DAYS | TGF α | TGF α +EBP | EBP | bFGF | EBP+bFGF | 1 β FCS+EBP | 1 β FCS+bFGF | 1 β FCS+EBP+bFGF | 1 β FCS | NT |
|------|--------------|-------------------|------|------|----------|-------------------|--------------------|------------------------|---------------|----|
| 2 | -- | -- | -- | -- | +++ | ++ | ++1/2+ | ++ | -- | -- |
| 5 | -- | -- | -- | -- | ++ | +++ | +++ | +++ | + | -- |
| 7 | -- | -- | +/-- | -- | +/-- | +++ | ++ | ++ | -- | -- |
| 9 | -- | -- | +/-- | -- | -- | +++ | +++ | ++ | -- | -- |
| 12 | -- | -- | +/-- | -- | +/-- | +++ | +++ | ++ | -- | -- |

NT - not treated

D. Activity of EBP on Primary Cultures of Hepatocytes

Hepatocytes were isolated by the *in situ* two step collagenase perfusion technique described by Seglen (*Methods in Toxicol.*, Vol. 1A, 231-243 (1993)). Briefly, the perfused livers were dispersed in ice cold Hank's buffer, filtered through a nylon mesh, and hepatocytes separated from nonparenchymal cells by repeated centrifugation at 50 X g. The hepatocytes were determined to be greater than 85% viable by trypan blue exclusion. The hepatocytes were cultured on plates coated with rat tail collagen and plated in Williams E containing 5% FCS, 10^{-7} M insulin, 10^{-8} M dexamethason, glutamine, penicillin and streptomycin.

Cells were allowed to attach for 3-4 hours in serum containing media and then transferred to serum-free media. The appropriate concentrations of EBP or other growth factors were added and the cells were incubated for 24 to 48 hours in the presence of ^3H -thymidine. After incubation, the extent of ^3H -thymidine incorporation into cells was determined. The growth factors tested were keratinocyte growth factor (KGF) at 10 ng/ml, acidic FGF (aFGF) at 20 ng/ml, and EBP at 20ng/ml. The results are shown in Figure 9. The amount of ^3H -thymidine incorporation stimulated by EBP is about the same as that induced by aFGF. The combination of KGF and EBP did not stimulate hepatocyte growth over the level observed by KGF alone. In this particular experiment, the serum free value was unusually high (about 3-fold).

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* * *

While the present invention has been described in terms of the preferred embodiments, it is understood
5 that variations and modifications will occur to those skilled in the art. Therefore, it is intended that the appended claims cover all such equivalent variations which come within the scope of the invention as claimed.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT: Bartley, Timothy Dudley
Fox, Gary Michael
Boyle, William James
Welcher, Andrew Avery
Parker, Vann Phillips

(ii) TITLE OF INVENTION: Eck Receptor Ligands

(iii) NUMBER OF SEQUENCES: 16

(iv) CORRESPONDENCE ADDRESS:

(A) ADDRESSEE: Amgen Inc.

(B) STREET: Amgen Center
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(C) CITY: Thousand Oaks

(D) STATE: California

(E) COUNTRY: USA

(F) ZIP: 91320-1789

(v) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Diskette, 3.5 in., DS, 2.0 Mb

(B) COMPUTER: Apple Macintosh

(C) OPERATING SYSTEM: Macintosh OS 7.0

(D) SOFTWARE: Microsoft Word Version 5.1a

(vi) CURRENT APPLICATION DATA:

(A) APPLICATION NUMBER:

(B) FILING DATE:

(C) CLASSIFICATION:

(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 205 amino acids

(B) TYPE: amino acid

(C) STRANDEDNESS: single-stranded

(D) TOPOLOGY: unknown

53

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

```

Met Glu Phe Leu Trp Ala Pro Leu Leu Gly Leu Cys Cys Ser
-15- -10 -5

Leu Ala Ala Ala Asp Arg His Thr Val Phe Trp Asn Ser Ser
1 5 10

Asn Pro Lys Phe Arg Asn Glu Asp Tyr Thr Ile His Val Gln
15 20

Leu Asn Asp Tyr Val Asp Ile Ile Cys Pro His Tyr Glu Asp
25 30 35

His Ser Val Ala Asp Ala Ala Met Glu Gln Tyr Ile Leu Tyr
40 45 50

Leu Val Glu His Glu Glu Tyr Gln Leu Cys Gln Pro Gln Ser
55 60 65

Lys Asp Gln Val Arg Trp Gln Cys Asn Arg Pro Ser Ala Lys
70 75 80

His Gly Pro Glu Lys Leu Ser Glu Lys Phe Gln Arg Phe Thr
85 90

Pro Phe Thr Leu Gly Lys Glu Phe Lys Glu Gly His Ser Tyr
95 100 105

Tyr Tyr Ile Ser Lys Pro Ile His Gln His Glu Asp Arg Cys
110 115 120

Leu Arg Leu Lys Val Thr Val Ser Gly Lys Ile Thr His Ser
125 130 135

Pro Gln Ala His Val Asn Pro Gln Glu Lys Arg Leu Ala Ala
140 145 150

Asp Asp Pro Glu Val Arg Val Leu His Ser Ile Gly His Ser
155 160

Ala Ala Pro Arg Leu Phe Pro Leu Ala Trp Thr Val Leu Leu
165 170 175

Leu Pro Leu Leu Leu Leu Gln Thr Pro
180 185

```

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

AAGCATATGG ATCGCCACAC CGTCTTCTGG

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 35 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

GAAGGATCCT TATCACGGGG TTGCAGCAG CAGAA

35

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 36 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

GAAGGATCCC TATTATGCTG CAAGTCTCTT CTCCTG

36

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 31 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

GAATTCAAGC TTCAGGCCCC GCGCTATGGA G

31

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 35 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

55

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

GAATTCTCTA GATCATCACG GGGTTTGCAG CAGCA

35

(2) INFORMATION FOR SEQ ID NO:7:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 13 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

AGCTTAGATC TCC

13

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 13 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

AATTGGAGAT CTA

13

(2) INFORMATION FOR SEQ ID NO:9:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 39 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

AATTCCAGAC GCTGTCCCCG GAGGGATCCG GCAACTGAG

(2) INFORMATION FOR SEQ ID NO:10:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 39 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

TCGACTCAGT TGCCGGATCC CTCCGGGGAC AGCGTCTGG

39

(2) INFORMATION FOR SEQ ID NO:11:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1480 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

| | |
|---|-----|
| GCGGAGAAAG CCAGTGGGAA CCCAGACCCA TAGGAGACCC GCGTCCCCGC TCGGCCTGGC | 60 |
| CAGGCCCCGC GCT ATG GAG TTC CTC TGG GCC CCT CTC TTG GGT CTG TGC | 109 |
| Met Glu Phe Leu Trp Ala Pro Leu Leu Gly Leu Cys | |
| 1 5 10 | |
| TGC AGT CTG GCC GCT GCT GAT CGC CAC ACC GTC TTC TGG AAC AGT TCA | 157 |
| Cys Ser Leu Ala Ala Ala Asp Arg His Thr Val Phe Trp Asn Ser Ser | |
| 15 20 25 | |
| AAT CCC AAG TTC CGG AAT GAG GAC TAC ACC ATA CAT GTG CAG CTG AAT | 205 |
| Asn Pro Lys Phe Arg Asn Glu Asp Tyr Thr Ile His Val Gln Leu Asn | |
| 30 35 40 | |
| GAC TAC GTG GAC ATC ATC TGT CCG CAC TAT GAA GAT CAC TCT GTG GCA | 253 |
| Asp Tyr Val Asp Ile Ile Cys Pro His Tyr Glu Asp His Ser Val Ala | |
| 45 50 55 60 | |
| GAC GCT GCC ATG GAG CAG TAC ATA CTG TAC CTG GTG GAG CAT GAG GAG | 301 |
| Asp Ala Ala Met Glu Gln Tyr Ile Leu Tyr Leu Val Glu His Glu Glu | |
| 65 70 75 | |
| TAC CAG CTG TGC CAG CCC CAG TCC AAG GAC CAA GTC CGC TGG CAG TGC | 349 |
| Tyr Gln Leu Cys Gln Pro Gln Ser Lys Asp Gln Val Arg Trp Gln Cys | |
| 80 85 90 | |
| AAC CGG CCC AGT GCC AAG CAT GGC CCG GAG AAG CTG TCT GAG AAG TTC | 397 |
| Asn Arg Pro Ser Ala Lys His Gly Pro Glu Lys Leu Ser Glu Lys Phe | |
| 95 100 105 | |
| CAG CGC TTC ACA CCT TTC ACC CTG GGC AAG GAG TTC AAA GAA GGA CAC | 445 |
| Gln Arg Phe Thr Pro Phe Thr Leu Gly Lys Glu Phe Lys Glu Gly His | |
| 110 115 120 | |
| AGC TAC TAC TAC ATC TCC AAA CCC ATC CAC CAG CAT GAA GAC CGC TGC | 493 |
| Ser Tyr Tyr Tyr Ile Ser Lys Pro Ile His Gln His Glu Asp Arg Cys | |
| 125 130 135 140 | |
| TTG AGG TTG AAG GTG ACT GTC AGT GGC AAA ATC ACT CAC AGT CCT CAG | 541 |
| Leu Arg Leu Lys Val Thr Val Ser Gly Lys Ile Thr His Ser Pro Gln | |
| 145 150 155 | |

| | |
|--|------|
| GCC CAT GTC AAT CCA CAG GAG AAG AGA CTT GCA GCA GAT GAC CCA GAG | 589 |
| Ala His Val Asn Pro Gln Glu Lys Arg Leu Ala Ala Asp Asp Pro Glu | |
| 160 165 170 | |
| GTG CGG GTT CTA CAT AGC ATC GGT CAC AGT GCT GCC CCA CGC CTC TTC | 637 |
| Val Arg Val Leu His Ser Ile Gly His Ser Ala Ala Pro Arg Leu Phe | |
| 175 180 185 | |
| CCA CTT GCC TGG ACT GTG CTG CTC CTT CCA CTT CTG CTG CTG CAA ACC | 685 |
| Pro Leu Ala Trp Thr Val Leu Leu Leu Pro Leu Leu Leu Gln Thr | |
| 190 195 200 | |
| CCG TGAAGGTGTA TGCCACACCT GGCCTTAAAG AGGGACAGGC TGAAGAGAGG | 738 |
| Pro | |
| 205 | |
| GACAGGCACT CCAAACCTGT CTTGGGGCCA CTTTCAGAGC CCCCAGCCCT GGGAACCACT | 798 |
| CCCACCACAG GCATAAGCTA TCACCTAGCA GCCTCAAAAC GGGTCAGTAT TAAGGTTTTTC | 858 |
| AACCGGAAGG AGGCCAACCA GCCCGACAGT GCCATCCCCA CCTTCACCTC GGAGGGACGG | 918 |
| AGAAAGAAGT GGAGACAGTC CTTTCCCACC ATTCCTGCCT TTAAGCCAAA GAAACAAGCT | 978 |
| GTGCAGGCAT GGTCCCTTAA GGCACAGTGG GAGCTGAGCT GGAAGGGGCC ACGTGGATGG | 1038 |
| GCAAAGCTTG TCAAAGATGC CCCCTCCAGG AGAGAGCCAG GATGCCCAGA TGAAGTACT | 1098 |
| GAAGGAAAAG CAAGAAACAG TTTCTTGCTT GGAAGCCAGG TACAGGAGAG GCAGCATGCT | 1158 |
| TGGGCTGACC CAGCATCTCC CAGCAAGACC TCATCTGTGG AGCTGCCACA GAGAAGTTTG | 1218 |
| TAGCCAGGTA CTGCATTCTC TCCCATCCTG GGGCAGCACT CCCCAGAGCT GTGCCAGCAG | 1278 |
| GGGGGCTGTG CCAACCTGTT CTTAGAGTGT AGCTGTAAGG GCAGTGCCCA TGTGTACATT | 1338 |
| CTGCCTAGAG TGTAGCCTAA AGGGCAGGGC CCACGTGTAT AGTATCTGTA TATAAGTTGC | 1398 |
| TGTGTGTCTG TCCTGATTTT TACAAGTGA GTTTTTTTAT ACAATGTTCT TTGTCTCAAA | 1458 |
| ATAAAGCAAT GTGTTTTTTC GG | 1480 |

59

(2) INFORMATION FOR SEQ ID NO:12:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 5 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: unknown

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

Lys Arg Leu Ala Ala
1 5

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 23 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: unknown

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

Asp Arg His Thr Val Phe Asp Asn Ser Ser Asn Pro Lys Phe Arg Asn Glu Asp Tyr
1 5 10 15
Ile His Val Gln
20

(2) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 40 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

GAATTCTCTA GATTTCATGG AAGGAGCAGC ACAGTCCAG

(2) INFORMATION FOR SEQ ID NO:15:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 39 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

GAATTCTCTA GATTATCATG GGAAGAGGCG TGGGGCAGC

39

(2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 41 nucleotides
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single-stranded
- (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

GAATTCTCTA GATTATCATG GGGCAGCACT GTGACCGATG C

41

WHAT IS CLAIMED IS:

1. A purified and isolated polypeptide specifically binding the *eck* receptor and having
5 substantially the same amino acid sequence as shown in SEQ. ID. NO. 1.
2. The polypeptide of Claim 1 which induces phosphorylation of the *eck* receptor.
10
3. The polypeptide of Claim 1 having an amino acid sequence as shown in SEQ. ID. NO. 1 terminating at position 150 or having substantially the same amino acid
15 sequence as shown in SEQ. ID. NO. 1 terminating at position 150.
4. The polypeptide of Claim 3 wherein the amino acid sequence is from position +1 to 150 as shown in SEQ. ID. NO. 1.
20
5. The polypeptide according to Claim 1 having a methionine residue at position -1.
6. The polypeptide according to Claim 5
25 selected from the group consisting of [Met⁻¹] EBP¹⁻¹⁵⁰ and [Met⁻¹] EBP¹⁻¹⁵⁹.
7. The polypeptide according to Claim 1 selected from the group consisting of EBP¹⁻¹⁶⁷, EBP¹⁻¹⁷¹
30 and EBP¹⁻¹⁸⁰.
8. The polypeptide of Claim 1 which is characterized by being the product of procaryotic or eucaryotic expression of an exogenous DNA sequence.
35

9. The polypeptide of Claim 8 which is the product of CHO cell expression.

10. The polypeptide of Claim 8 wherein the
5 exogenous sequence is a cDNA sequence.

11. The polypeptide of Claim 8 wherein the exogenous sequence is a genomic DNA sequence.

10 12. The polypeptide of Claim 8 wherein the exogenous sequence is a synthetic DNA sequence.

13. The polypeptide of Claim 8 wherein the exogenous DNA sequences is carried on an autonomously
15 replicating DNA plasmid or viral vector.

14. The polypeptide of Claim 8 which is the product of *E. coli* expression.

20 15. The polypeptide of Claim 8 having an N-terminal methionine residue.

16. A DNA sequence encoding a polypeptide specifically binding the eck receptor, wherein said
25 polypeptide has a methionine residue at position -1 and has substantially the same amino acid sequence as shown in SEQ. ID. NO. 1.

17. A DNA sequence according to Claim 16
30 encoding (Met⁻¹) EBP¹⁻¹⁵⁰ and [Met⁻¹] EBP¹⁻¹⁵⁹.

18. A DNA sequence encoding EBP¹⁻¹⁶⁷, EBP¹⁻¹⁷¹ and EBP¹⁻¹⁸⁰.

35 19. An isolated eck receptor-ligand complex.

20. The receptor-ligand complex according to Claim 13 wherein the ligand is the polypeptide according to Claim 1.

5 21. A method for detecting in crude samples a ligand capable of binding to a receptor comprising the steps of:

 a) immobilizing a purified ligand binding domain of the receptor;

10 b) contacting the immobilized receptor with conditioned medium containing the ligand; and

 c) monitoring the binding of the ligand to the immobilized receptor by a surface plasmon resonance detection system.

15

22. The method of Claim 21 wherein the receptor is the eck receptor.

23. A method of modulating the endogenous activity of an eck receptor in a mammal comprising administering to the mammal an effective amount of a ligand to the eck receptor to modulate the activity of said receptor.

25 24. The method according to Claim 23 wherein the ligand is the polypeptide of Claim 1.

25 25. The method according to Claim 23 wherein the modulation of said eck receptor activity regulates cellular functions comprising differentiation, proliferation and metabolism.

35 26. A method for identifying compounds that modulate the activity of an eck receptor comprising the steps of:

a) exposing cells exhibiting the receptor to known ligands for a time sufficient to allow formation of receptor-ligand complexes and induce signal transduction;

5 b) determining the extent of activity within the cells; and

c) comparing the measured activity to the activity in cells not exposed to the ligand.

10 27. A method for the treatment of cancer in a patient comprising administering a therapeutically effective amount of an eck receptor ligand.

15 28. A method for the treatment of cancer in a patient comprising administering a therapeutically effective amount of the ligand of Claim 27 wherein said ligand binds to, but does not phosphorylate the eck receptor.

20 29. A method for the treatment of cancer in a patient comprising administering a therapeutically effective amount of an eck soluble receptor.

25 30. A method as in either of Claims 27, 28 or 29 further comprising a therapeutically effective amount of chemotherapy or radiation therapy.

30 31. A method for the treatment of inflammation in a patient comprising administering a therapeutically effective amount of an eck soluble receptor.

35 32. A method for the treatment of inflammation in a patient comprising administering a therapeutically effective amount of an eck receptor

ligand wherein said ligand binds to, but does not phosphorylate the eck receptor.

33. A method for the treatment of a wound in
5 a mammal comprising administering a therapeutically effective amount of an eck receptor ligand.

34. A method for increasing hematopoiesis in
a mammal comprising administering a therapeutically
10 effective amount of an eck receptor ligand.

35. The method according to Claim 34 wherein the ligand is the polypeptide of Claim 1.

15 36. A method for stimulating proliferation of colon cells comprising administering a therapeutically effective amount of an eck receptor ligand.

37. The method according to Claim 36 which is
20 used in conjunction with cancer therapy.

38. The method according to Claim 36 wherein the ligand is the polypeptide of Claim 1.

25 39. A method for stimulating proliferation of hepatocytes comprising administering a therapeutically effective amount of an eck receptor ligand.

40. A method according to Claim 39 wherein
30 the ligand is the polypeptide of Claim 1.

41. A pharmaceutical composition comprising a therapeutically effective amount of an eck receptor ligand and a pharmaceutically acceptable diluent,
35 adjuvant or carrier.

42. A pharmaceutical composition comprising a therapeutically effective amount of an eck soluble receptor and a pharmaceutically acceptable diluent, adjuvant or carrier.

5

43. A composition comprising the polypeptide of Claim 1 and a detergent.

1 / 9

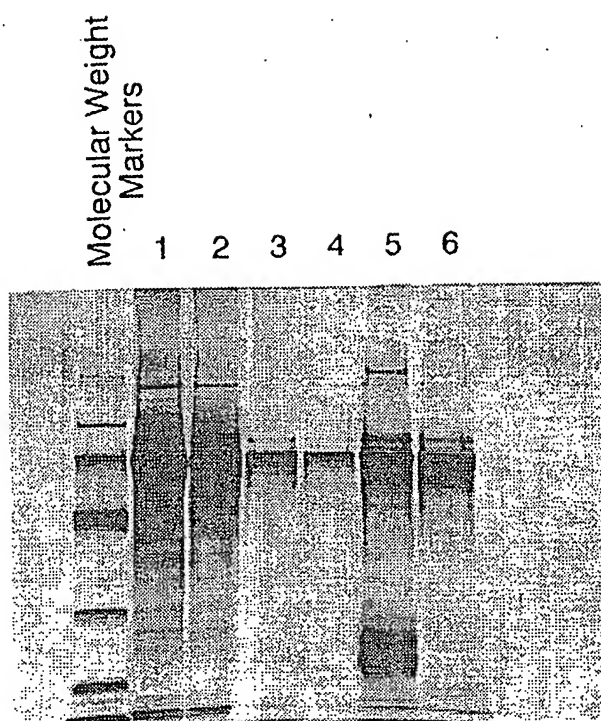


FIG. 1A

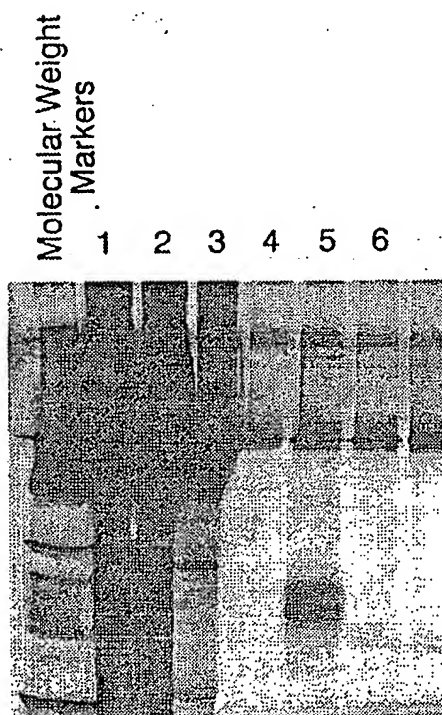


FIG. 1B

2 / 9

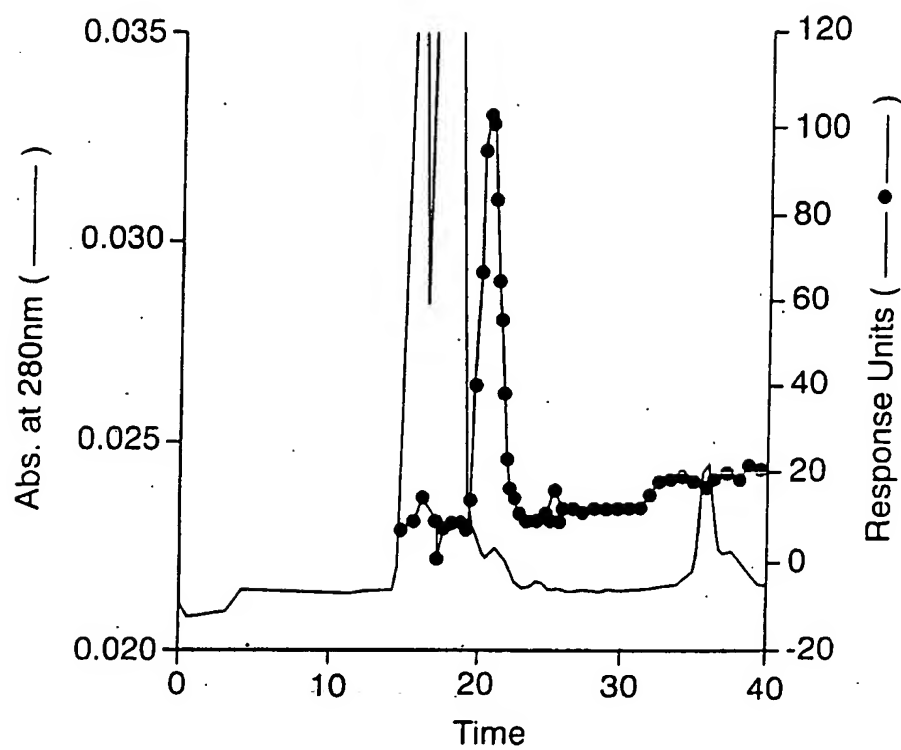
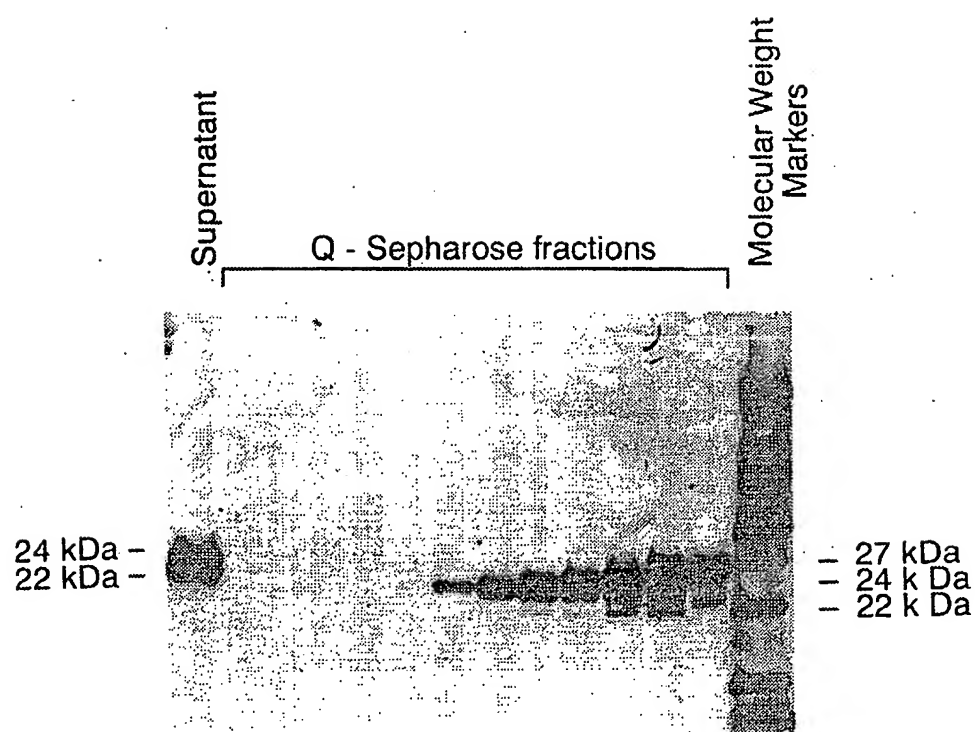


FIG. 2

3 / 9

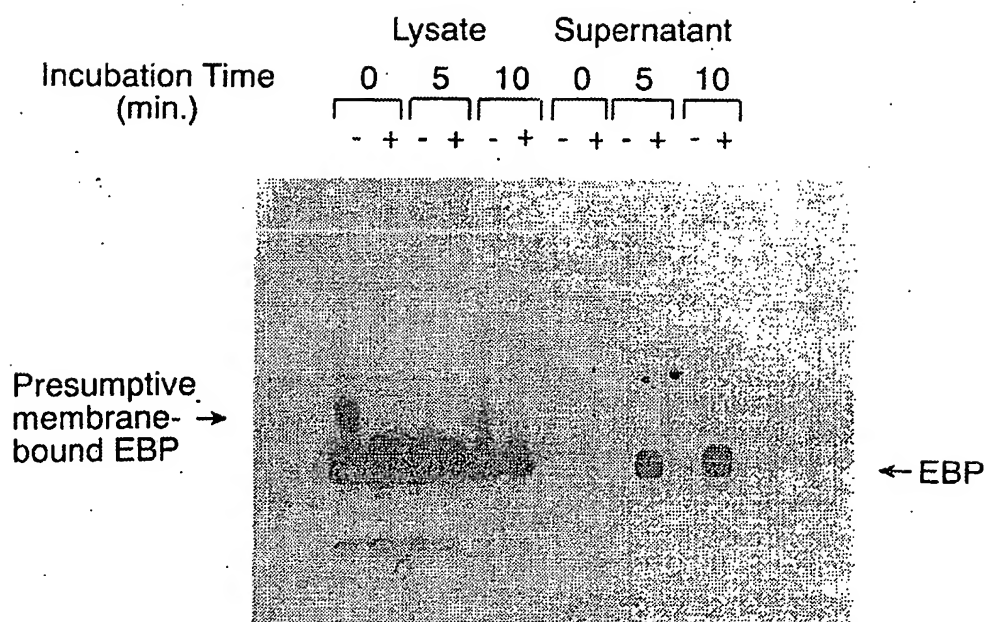
FIG. 3



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4 / 9

FIG. 4



5 / 9

FIG. 5

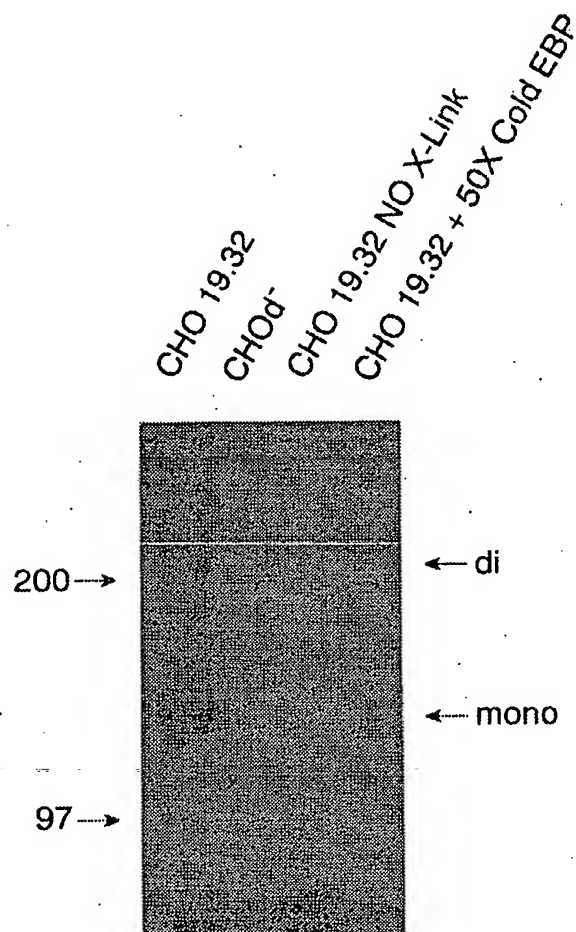
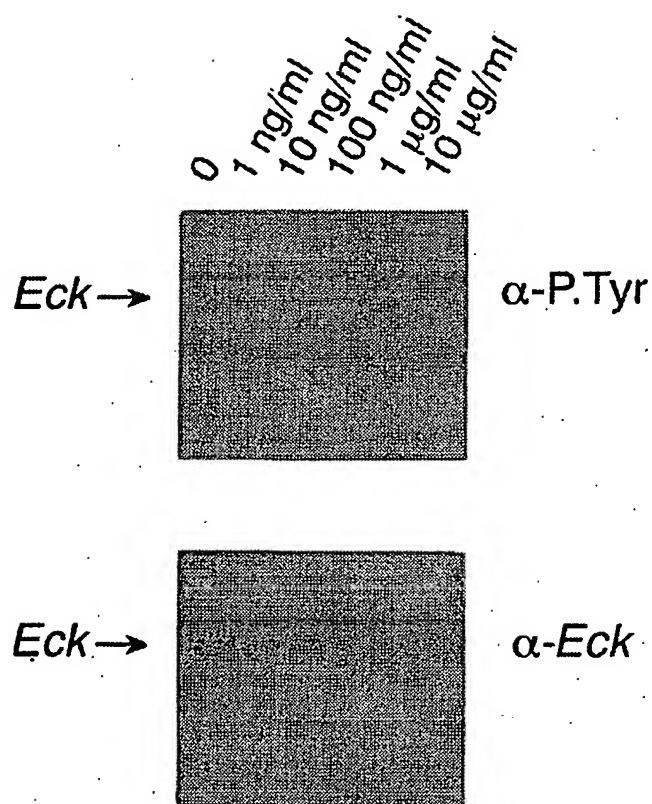
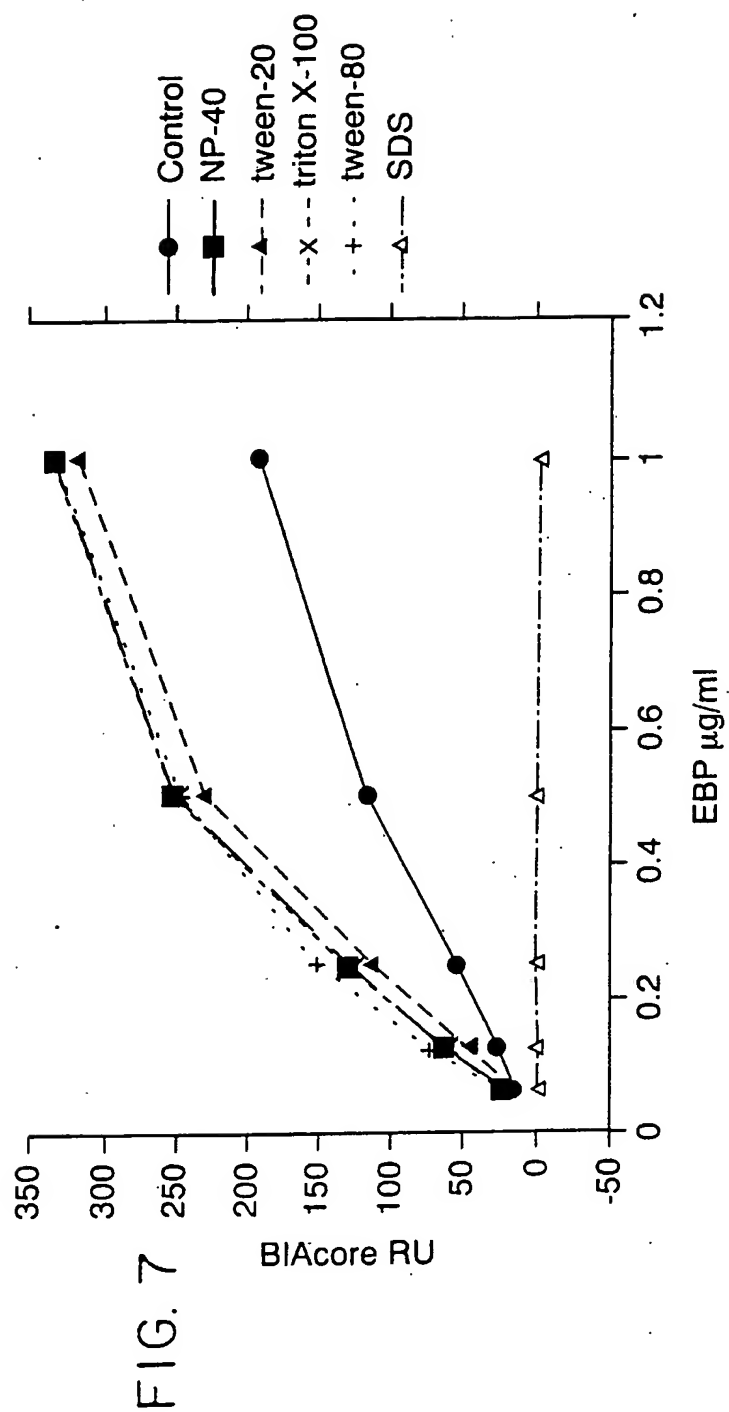


FIG. 6





8 / 9

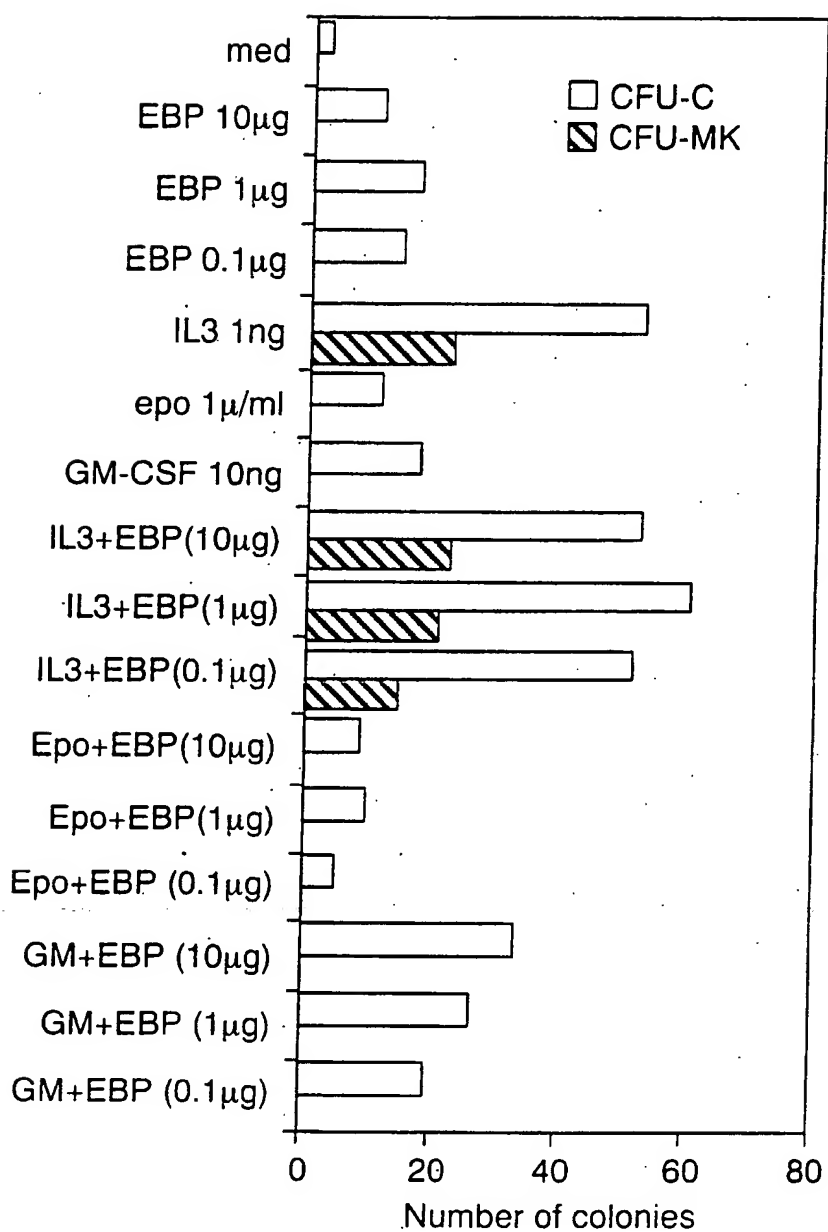
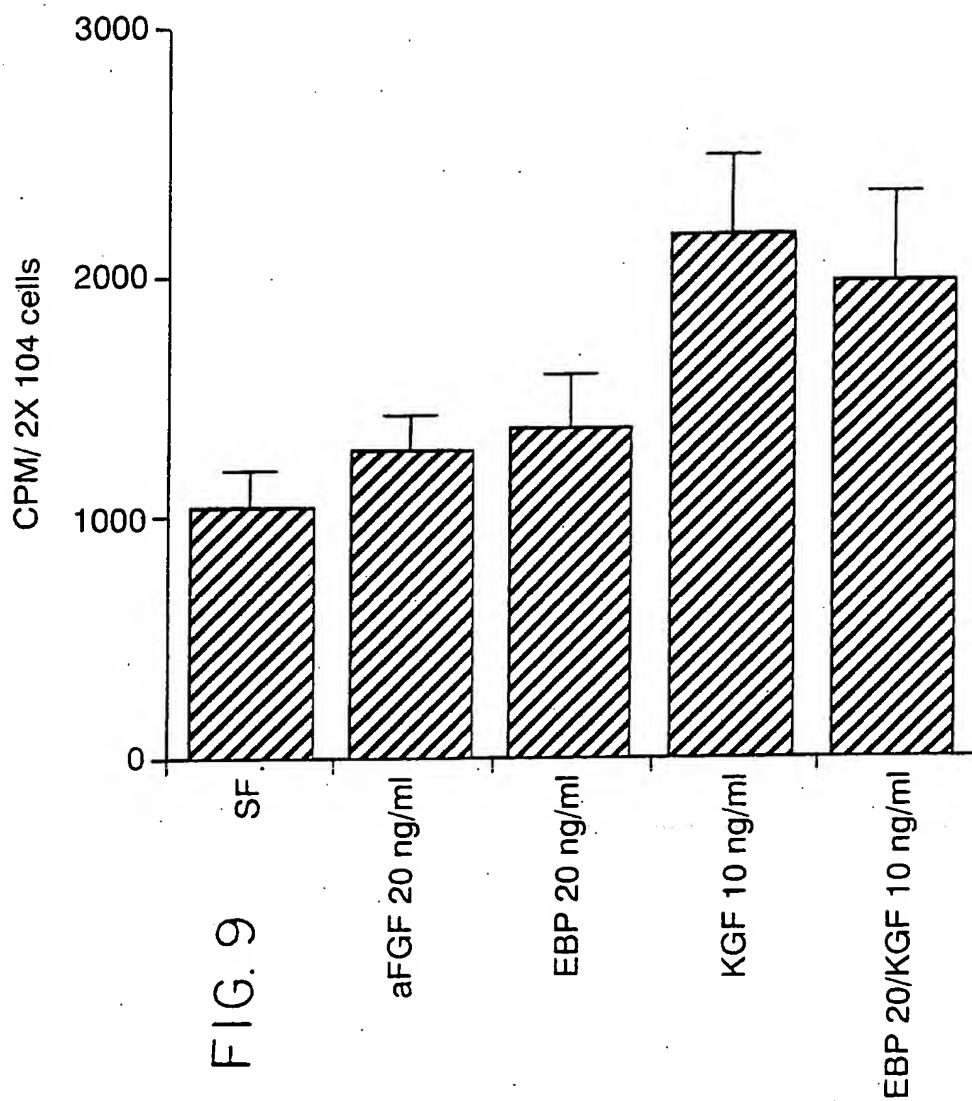


FIG. 8

9 / 9



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US93/10879

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :A61K 37/02, 37/52; C07K 13/00; C12N 15/12; C12Q 1/48

US CL :424/94.5; 435/7.1, 7.2; 514/12; 530/350; 536/23.5

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 424/94.5; 435/7.1, 7.2; 514/12; 530/350; 536/23.5

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, Dialog

search terms: eck, B61, ligand, bind?, receptor

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---------------|---|--------------------------------|
| X --- Y | Molecular and Cellular Biology, Vol. 10, No. 11, issued November 1990, L. B. Holzman et al., "A novel immediate-early response gene of endothelium is induced by cytokines and encodes a secreted protein", pages 5830-5838, see page 5834. | 1-18, 41, 43 ----- 19-26 |
| X --- Y | WO, A, 92/07094 (Dixit) 30 April 1992, see pages 11-12 and Figure 3A. | 1-18, 41, 43 ----- 19-26 |



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Date of the actual completion of the international search

20 December 1993

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/10879

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-------------|--|-----------------------|
| X — Y | Molecular and Cellular Biology, Vol. 10, No. 12, issued December 1990, R. A. Lindberg et al., "cDNA cloning and characterization of <u>eck</u> , an epithelial cell receptor protein-tyrosine kinase in the <u>eph/elk</u> family of protein kinases", pages 6316-6324, see the entire document. | 42 — 19-26 |
| Y | BioTechniques, Vol. 11, No. 5, issued 1991, U. Jonsson et al., "Real-time biospecific interaction analysis using surface plasmon resonance and a sensor chip technology", pages 620-627, see the entire document. | 21, 22 |

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